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ORIGINAL ARTICLES

ON THE BIOLOGY AND CONTROL OF CODLING MOTH (*CYDIA POMONELLA* LINN.) IN BALUCHISTAN

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(With one text-figure)

THE codling moth [*Cydia pomonella* (Linn.) : Fam. Eucosmidae : Lepidoptera], one of the worst pests of apples, pears and quinces, is firmly established in many orchards of Baluchistan. Due to the constant ravages of this insect, about 80 per cent of apples are infested yearly in Baluchistan, and a fairly large number of valuable apple orchards have been cut down in the Quetta valley during recent years.

An account of the distribution, status and biology of the codling moth in Baluchistan was published by Pruthi [1938]. A popular account of various control measures advocated against this pest was published by Roy [1941] and the preliminary results of insecticidal tests for codling moth control in Baluchistan have also been described by Mustafa and Janjua [1942]. In view of the seriousness of the pest in this area, detailed studies on the biology and control measures were made by the writers during 1936-40, and the results are presented in this paper.

Distribution

The insect has been recorded from almost all the apple-growing countries of the world. It is a serious pest in Europe, the United States of America, Canada, North and South Africa, Australia, New Zealand, Palestine and Afghanistan. In India the pest occurs only in Baluchistan and the North-West Frontier Province. There is, however, a doubtful record of its occurrence from Dras Ladakh (Kashmir) as well [Fletcher, 1919]. In Baluchistan, the pest is widely distributed in the Quetta-Pishin district and Fort Sandeman (Zhob district) ; it also occurs at Mastung and Kalat.

Introduction of the pest into Baluchistan

Janjua [1938] recorded the codling moth as a serious pest of apples in Afghanistan and the subsequent observations of Dr Taskhir Ahmad, a member

of the Indian Agricultural Delegation to Afghanistan, has confirmed this assumption [Mustafa, Mundkur & Ahmad, 1939]. Till the middle of the nineteenth century, northern Baluchistan was an important province of Afghanistan. Very little attention was then paid to fruit-growing. With the area coming under British control in 1879, encouragement was given to the fruit industry and numerous orchards were established, importing most of the nursery stock from Kandhar, Afghanistan [Buller, 1907]. As a result of this, the Kandhari apple is now a well-established variety in Baluchistan. Also, since 1890, when the railway was extended to Chaman, apples along with other fruits began to be imported on a large scale from Kandhar, and Baluchistan became the distributing centre for India. A still greater impetus was given to this trade by the introduction of ice vans. In view of the nature of the life-history of the pest, the most common mode of its spread from one place to another is through the transport of infested fruit. For the past half century, apples from Kandhar have been coming in regularly and it is presumed that the infested fruit must have brought larvae with them and the pest, finding the climatic conditions and the host-plant ideal for its propagation in Baluchistan, gradually established itself and is now a pest of first rate importance. In view of the short period in which its life-cycle is completed, it is very improbable that the pest can reach Baluchistan while being carried inside infested apples imported by sea from Europe, the United States, North and South Africa, Australia, etc. The writers agree with Pruthi [1938] in believing the codling moth to have been introduced from Afghanistan into India.

NATURE OF DAMAGE

Apples, pears and quinces attacked by the larvae of this pest have holes eaten either into the side or from the blossom or stalk end to the core. Dark masses of 'frass' often protrude from these holes. If such fruit is split open, it will be seen that the seeds have been eaten, the core tunnelled through and that the whole area is black and rotting making the fruit unfit for human consumption. The infested fruit usually presents an emaciated and sometimes stunted appearance and very often falls to the ground even with moderately strong wind.

A form of injury less familiar is the 'sting' injury which results from a newly hatched worm chewing the skin of the fruit without burrowing into it. Sometimes when a larva is unable to bore at a particular place, it leaves it and attacks at another point, thus producing a number of 'sting' injuries on the same fruit. Although these injuries are only skin deep, the fruit is invariably exposed to the attack of fungi and scavenger beetles of the family Nitidulidae from which a healthy fruit is usually immune. Rot sets in as a result thereof and the fruit is spoiled.

It has been ascertained that in the Quetta-Pishin district about 80 per cent of apples are infested by this pest, while at Fort Sandeman (Zhob district) the infestation is about 60 per cent [Pruthi, 1938]. Pears and quinces are also attacked almost to the same extent.

LIFE-HISTORY

Immature stages

The various immature stages and the life-history of the codling moth have been previously described in detail by Pruthi [1938]. Therefore, only the

instars and the moults of the larvae are described here in detail. It has been ascertained that the larva undergoes five moults and thus there are six larval instars. The description of the various instars is as follows :—

First instar. Length of a newly hatched larva is 1·9 to 2·1 mm., head being 0·25 mm. in breadth. Soon after hatching, the larva is dirty-white, but ultimately turns creamy-white; head and thoracic shield dark brown; anal plate concolorous with the body; thoracic legs darker than the body colour; prolegs concolorous with the body. Body with a few long, white hairs.

Second instar. Length soon after moulting is 3·8 mm., head 0·42 mm. wide. General body colour creamy-white; head dark brown; thoracic shield a shade deeper than the head; anal plate shield-shaped, dark brown; thoracic legs very dark brown; prolegs concolorous with the body; tubercles distinct, light brown in colour, each bearing a single hair; hairs few, creamy-white, moderately long.

Third instar. Length soon after moulting is 5·7 mm., head 0·52 mm. wide. General body colour creamy-white but gradually acquires a pinkish tinge; head somewhat pale brown; thoracic shield dark brown; anal plate shield-shaped and a shade deeper than the body; thoracic legs dark brown; prolegs concolorous with the body; tubercles distinct, shiny; hairs moderately long, sparse, white; spiracles small, round and ringed with black.

Fourth instar. Length after moulting is 7·6 mm., head 0·69 mm. wide. General body colour creamy-white with a pinkish tinge; head very dark brown; thoracic shield much darker than the head; anal plate shield-shaped and light brown; thoracic legs light brown bearing many bristle-like hairs; prolegs concolorous with the body; tubercles conspicuous, shiny and concolorous with the body; hairs short, white, sparse; edges of spiracles raised, pimple-like, darker than general body colour. Head, thoracic shield and anal plate bear silky hairs.

Fifth instar. Length after moulting is 8·3 mm. to 9·1 mm., head 0·79 mm. wide. General body colour pinkish-white; head dark brown, shiny; mouth-parts brown; anal plate shield-shaped, darker than the body colour; thoracic legs creamy-white bearing many bristle-like hairs; prolegs concolorous with the body; tubercles inconspicuous, flat, spreading, coarsely pitted, each bearing a long yellow setae; hairs sparse, white; spiracles round, small, ringed with black. Head, pro-thoracic shield and anal plate bearing silky hairs.

Sixth instar (full-grown larva). Length 12·9 to 14·6 mm. and breadth 1·75 mm. across the first abdominal segment, head almost as long as wide (1·5 mm.). General body colour bright pink especially on dorsal side; head dark brown, shiny, spherical when viewed from above; its surface covered by several pairs of setae; mouth-parts brown, lighter than head; antennae three-segmented, the distal end of the first segment having a long hair; labium and its palpi prominent; pro-thoracic shield becomes much lighter as the larva advances in age; thoracic legs dark creamy-white; prolegs concolorous with the body; crotchets black and arranged in complete circles, except on the last pair on which they are semi-circular; anal plate dark, highly chitinized; tubercles oval, slightly darker in colour than body, coarsely pitted; spiracles

conspicuous, round, ringed with black. The body bears short hairs arising singly.

Duration of various stages, seasonal-history and number of generations

The seasonal-history of codling moth varies considerably under different climatic conditions. In the United States of America, at certain places, such as the Pacific North-west [Newcomer, Yother & Whitcomb, 1924] there are two broods in a year, while in South-west Idaho [Wakeland & Rice, 1932], Delaware [Selkregg & Siegler, 1928] and Yakima valley [Newcomer & Whitcomb, 1924] there are three broods and in the warmest southern provinces there are even four broods [Van Leeuwen, 1929]. There are two generations and a partial third one of the codling moth in South Africa [Pettey, 1932] and New South Wales [Allman, 1928]. In Canada and England there is one brood, sometimes two broods in a year [Adkin, 1935]. An account of the seasonal-history of the insect in Baluchistan for 1937 has been given by Pruthi [1938]. As a result of our investigations during the last four years, it has been ascertained that there are two generations of the codling moth in the Quetta valley in a year. The studies were started in the laboratory with the first-brood eggs deposited during 1936 and subsequently confirmed by field observations.

First generation

Eggs of the first brood. During 1936, the eggs were first deposited on April 12, but oviposition continued up to May 19. The dates during 1937, 1938 and 1939 were April 9, 15 and 10 and oviposition continued up to May 16, 22 and 20 respectively. They are laid singly but occasionally two or three may be found together. Majority of them are deposited on the upper surfaces of the leaves near a cluster of newly set fruit, but sometimes a few are found on fruit as well. The incubation period varies from 5 to 14 days with an average of 9·3 days. In 1936 it varied from 7 to 13 days, in 1937 from 6 to 14 days, in 1938 from 7 to 13 days while in 1939 from 5 to 14 days. A day or two before hatching, the egg loses its glistening appearance and a black spot appears. This is the head of the young larva, which when ready to emerge, may be seen to move its mandibles to cut through the shell.

Larvae of the first brood. During 1936, eggs commenced hatching on April 25 and continued uptil May 26. In 1937 hatching started on April 23 and continued uptil May 22, in 1938 they commenced hatching on April 27 and continued uptil May 29, while in 1939 hatching was in progress from April 24 to May 25. A newly hatched larva moves about and sometimes nibbles a little of the undersurface of the leaf here and there until fruit is reached. The first-brood larvae enter the newly set fruit either at the calyx or stalk end or at any other point on the fruit. The feeding period of the larvae ranged from 12 to 44 days with an average of 25·5 days; in 1936 it was from 18 to 39 days, in 1937 from 18 to 40 days, in 1938 from 12 to 44 days while in 1939 it was from 16 to 40 days. The larva remains inside the fruit until it is full grown. At the end of the feeding period, the larvae leave the fruit through exit holes and seek some suitable sheltered places under which they spin cocoons. The attack of Quetta borer (*Aeolesthes sarta* Solsky) is common in the orchards of Baluchistan and the galleries made by the grubs of this beetle on apple

stems afford suitable places for the larvae to form cocoons. The cocoons are also found under loose bark of trunk and branches, in cracks of stumps and also in the grasses and other weeds near the base of the trunk. The cocoons spun by the first-brood larvae are thinner than those formed by the overwintering larvae. Before pupating, the larva excavates a short passage for the pupa to wriggle out.

The pre-pupal period, which begins from the time the larva leaves the fruit and ends with pupation, varied from a minimum of 5 days to a maximum of 16 days with an average of 9·3 days. In 1936 it varied from 6 to 14 days, in 1937 from 7 to 12 days, in 1938 from 5 to 18 days while in 1939 it varied from 6 to 15 days.

Pupae of the first brood. During 1936, the first pupation took place on June 9 and the last one on July 7. During 1937, 1938 and 1939 the first pupation was recorded on June 12, 10 and 11 and the last one on July 9, 8 and 18 respectively. The pupal period varied from 7 to 17 days with an average of 11·6 days. In 1936 it varied from 9 to 15 days, in 1937 from 7 to 14 days, in 1938 from 8 to 16 days while in 1939 from 8 to 17 days.

Moths of the first brood. When the moth is about to emerge, the pupa wriggles out of the cocoon, till it reaches the surface through the passage which was previously prepared by the larva. The case splits open and the adult moth emerges leaving about two-thirds of the pupal case protruding from the exit hole. In 1936, the first moths of this brood emerged on June 24 and the last on July 21. The dates of first emergence during the three subsequent years were June 25, 22 and 26 and emergence continued uptil July 20, 24 and 28 respectively. The length of life of the adult varied from 3 to 12 days, the average being 8·6 days during June-July, 1938. The females lived a day longer than the males.

Copulation takes place soon after the adults emerge and lasts from an hour to an hour and a half. Invariably it takes place at night. The pre-oviposition period varied from 2 to 4 days with an average of 2·9 days. The average time of egg deposition was 9·9 days varying from 4 to 14 days. Table I gives the oviposition records for the first-brood moths in 1938.

TABLE I

Oviposition record of first-brood moths, 1938

Observation number	Number of moths	Date of			Number of days	
		Emergence	First oviposition	Last oviposition	Before oviposition	Of oviposition
1	2	June, 22	June, 24	June, 27	2	5
2	9	„ 29	July, 1	July, 3	2	4
3	8	July, 2	„ 4	„ 14	2	12
4	6	„ 3	„ 5	„ 10	2	7
5	4	„ 5	„ 7	„ 17	2	12
6	9	„ 7	„ 9	„ 20	2	13
7	3	„ 19	„ 22	„ 28	3	9
8	2	„ 22	„ 24	Aug., 1	2	10
				Average	2·1	9·0
				Maximum	3	13
				Minimum	2	4

The egg-laying activities of the moths were observed in detail. Oviposition usually occurs just after sunset and as the time of oviposition approaches, there are indications of excitement on the part of the female. After sometime, it becomes quiet when the tip of its abdomen touches the surface on which it rests. It slowly lifts its abdominal tip and lays an egg. This process is repeated until all the eggs are laid. The average number of eggs deposited by the first-brood moths was 41·3—ten females depositing 413 eggs. The maximum number of eggs deposited by a single female was 102.

Life-cycle of first generation. The life-cycle of the first generation varied from 55 to 78 days with an average of 65·2 days. In 1936 it varied from 61 to 78 days, in 1937 from 59 to 73 days, in 1938 from 55 to 72 days while in 1939 it ranged from 57 to 76 days.

Second generation

Eggs of the second brood. During 1936, the first eggs were deposited on June 26 and oviposition continued up to July 25. The dates during 1937, 1938 and 1939 were June 28, June 24 and June 30 and oviposition continued up to July 29, July 23 and August 1, respectively. Majority of the second-brood eggs are laid on the fruit though some are found on leaves as well. The incubation period varied from 5 to 11 days with an average of 8·2 days. In 1936 it varied from 5 to 11 days, in 1937 from 5 to 10 days, in 1938 from 7 to 10 days while in 1939 from 6 to 11 days.

Larvae of the second brood. During 1936, the eggs of the second brood commenced hatching on July 8 and continued up to August 3. In 1937 they started on July 5 and continued uptil August 5; in 1938 they commenced on July 7 and continued uptil August 1, while in 1939 they hatched on July 10 and continued uptil August 7. The young larvae enter the fruits which are by now fairly well developed, near the calyx-end or the stalk-end or from the side, often selecting a place where the fruit is already injured by some physiological or other agency. They enter healthy as well as infested fruit indiscriminately avoiding, however, the exit holes already made by the larvae of the first brood. The feeding period of the larvae ranged from 30 to 50 days with an average of 44·1 days; in 1936 from 30 to 47 days; in 1937 from 36 to 50 days; in 1938 from 33 to 49 days; and in 1939 from 34 to 45 days. When full grown, the larva stops feeding, leaves the fruit and seeks some suitable shelter for spinning its cocoon. During 1936, the first larva came out from the fruit on August 22 and the last one on September 14. The dates on which the first larva came out during 1937, 1938 and 1939 were August 28, 25 and 23 and the last one on September 23, 17 and 20 respectively. Suitable places of shelter for pupation are afforded by the loose bark and burrows made by the Quetta borer on apple stems. The cocoons are composed of interwoven silken threads, almost elliptical in shape incorporating in their walls some trash such as bits of bark, etc. Usually they are found in groups of 5 to 12 sometimes 20 or even more. The larva hibernates in this cocoon in a bent or curled condition and before it pupates, it remodels the cocoon, elongating it and building a long slender passage to the outside for the pupa to wriggle out. Securely enclosed in these cocoons the larvae pass the winter until the approach of the next spring season, when they change into pupae. The pre-pupation period including hibernation varied from 165 to 203 days with an

average of 191·1 days. During 1936-37 it ranged from 181 to 203 days, in 1937-38 from 179 to 192 days, in 1938-39 from 177 to 198 days while in 1939-40 from 165 to 201 days.

Pupae of the second brood. During 1937, the earliest pupation of over-wintering larvae occurred on March 15 and the last one on April 8. During 1938, 1939 and 1940 the first pupation was recorded on March 12, 10 and 14 and the last one on April 9, 8 and 10 respectively. The pupal period varied from 23 to 30 days with an average of 26·8 days. In 1937 it varied from 23 to 25 days in 1938 from 26 to 29 days, in 1939 from 24 to 30 days and in 1940 from 25 to 27 days.

Moths of the second brood. In 1937, the first moths of this brood emerged on April 8 and the last on April 31. The dates of first emergence during the three subsequent years were April 11, April 9 and April 13 and continued up to May 5, May 1 and May 6 respectively. The length of life of adult varied from 8 to 20 days, the average being 11·4 days during April-May 1939. The females lived a day longer than the males. The pre-oviposition period varied from 2 to 7 days with an average of 4·5 days. The duration of egg deposition varied from 6 to 19 days, the average being 11·5 days. Table II gives the oviposition records for the second-brood moths in 1939.

TABLE II

Oviposition record of second-brood moths, 1939

Observation number	Number of moths	Date of			Number of days	
		Emergence	First oviposition	Last oviposition	Before oviposition	Of oviposition
1	3	April, 9	April, 13	April, 15	4	6
2	6	,, 14	,, 17	,, 25	3	11
3	5	,, 16	,, 21	,, 29	5	13
4	6	,, 19	,, 25	,, 28	6	9
5	7	,, 20	,, 24	May, 3	4	13
6	4	,, 23	,, 25	,, 8	2	15
7	2	,, 26	,, 28	,, 10	2	14
8	5	,, 30	May, 3	,, 12	3	12
				Average	3·62	11·62
				Maximum	6	15
				Minimum	2	6

The average number of eggs deposited by the second-brood moths was 35·8—ten females depositing 358 eggs. The maximum number of eggs deposited by a single female was 83.

Life-cycle of second generation. The life-cycle of the second generation varied from 243 to 290 days with an average of 268·9 days. In 1936-37 it varied from 243 to 264 days, in 1937-38 from 259 to 290 days, in 1938-39 from 251 to 287 days and in 1939-40 from 262 to 275 days.

General summary. The summarized data on the important stages in life-history are given in Table III.

TABLE III

Summary of the life-history data of Cydia pomonella *(Linn.), 1936-39*

Stages in life-history	First generation			Second generation		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Incubation period of eggs (in days)	14	5	9·3	11	5	8·2
Larval feeding period (in days)	44	12	25·5	50	30	44·1
Pre-pupal period in days (First generation only)	16	5	9·3	*	*	*
Pre-pupal and hibernation period in days (Second generation only)	*	*	*	203	165	191·1
Pupal period (in days)	17	7	11·6	30	23	26·8
Pre-oviposition period (in days)	4	2	2·9	7	2	4·5
Oviposition period (in days)	14	4	9·9	19	6	11·5
Longevity of adults (in days)	12	3	8·6	20	8	11·4
Life-cycle (in days)	78	55	65·2	290	243	268·9

Natural enemies

In Baluchistan, only one parasite of the larva of codling moth, viz. *Paralitomastix variicornis* (Nees) (Encyrtidae : Chalcidoidea) has so far been observed in small numbers.

The hibernating caterpillars of the codling moth are affected by the extremes of climatic conditions prevailing in the Quetta valley and other parts of Baluchistan. The Indian house-sparrow, *Passer domesticus indicus*, which is a constant visitor of the fruit trees in alarming numbers and is a serious menace to the fruit-growers, sometimes comes to their aid by preying upon the wintering worms that often seek shelter under the bark of the tree-trunks or in the soil around the base of the trees. Occasional hoeing of the soil, therefore, exposes the hibernating larvae and pupae to such birds.

CONTROL METHODS ADOPTED IN BALUCHISTAN

Plan of spraying

Experiments on the control of codling moth were started in the beginning of 1936 and continued for three subsequent years. Four orchards at Quetta in which the fruit had seriously suffered from the attacks of codling moth in previous years were selected for experiments. Each garden contained two distinct blocks each of which was about an acre in size, and grown exclusively under the Kandhari variety and the other under the Kulu variety. The trees were 15 to 18 years old, 16 feet apart and mostly of uniform size. The height of the Kandhari trees was 20 to 25 ft. while that of the Kulu variety was 17 to 23 ft. A block contained 12 rows with 14 trees in each row. These were selected for spraying experiments each year. 'Four Oaks Bridgewater'

spraying machine, armoured rubber hose $\frac{1}{2}$ in. $\times$ 25 ft., bamboo lance 4 ft. long and a double swivel nozzle were used in spraying. In applying the spray, the nozzle was directed in such a way as to get a straight drive into the calyx cups. The trees were sprayed first at the top and then the lower portions by adjusting the nozzle. Spray material at the rate of about two gallons per tree per application was used and this quantity was sufficient to cover the trees thoroughly.

Time of spray applications

In all, one calyx and four cover sprays were applied and the object and timing of these are described as follows :—

(1) *Calyx spray*. The purpose of this spray was to deposit poison in the calyx cups when almost all the petals had fallen off and before the calyx cups had closed. This is an important factor in codling moth control, because the small larvae find the calyx cups convenient places for entering into the fruit. The proper time for the application of this spray was when the calyx lobes had formed into cups, and when approximately 90 per cent of the petals had fallen. The authors believe this spray to be an important one as data at hand have often shown that about 60 per cent of the larvae enter through the calyx cups on unsprayed trees.

(2) *Cover sprays*. Cover sprays are for the express purpose of covering the fruit with a protective material to act as a poison for the larvae at the time they would attempt to enter the fruit. They also serve as a coverage of the leaf surface where many of the larvae can also be poisoned. In all, four cover sprays were applied and their timing was so planned as to give coverage during the hatching of the larvae of each brood.

First cover spray. As the spring-brood moths continue to emerge for about a month, the eggs deposited by them continue to hatch for the same period. The first cover spray was, therefore, applied to kill those worms of the first brood which had hatched out of the eggs deposited in the middle of the egg-laying period. This spray was applied about three weeks after the calyx spray.

Second cover spray. This spray was applied about 10 days after the first cover spray, and is important, because the maximum number of first-brood worms are present in the orchard at this time. Moreover, abundant food is also available to them as the fruit begins to grow rapidly.

Third cover spray. The third cover spray was meant to protect the fruit from the attack of the earliest hatched second-brood worms, which usually start coming out in the first week of July. It was applied 10-12 days after the second cover spray.

Fourth cover spray. The fourth cover spray was scheduled about 20 days after the third cover spray, as at this time, the maximum number of second-brood worms are present in the orchard. If the worms are not under control by this time, later sprays can do little good and will only result in excessive quantities of poison residue being left on the fruit at picking time.

Table IV gives the actual spraying dates together with the blossoming periods of the Kulu and the Kandhari varieties of apples in the four selected gardens at Quetta during the years 1936-39.

TABLE IV

Blossoming periods and spraying dates on Kulu and Kandhari varieties of apples 1936-39

Year	Variety	Full blossom	All petals dropped	Calyx spray	First cover spray	Second cover spray	Third cover spray	Fourth cover spray	Fruit picked
1936	Kulu .	April, 20	April, 25	April, 23	May, 13	May, 23	July, 4	July, 24	September, 20
	Kandhari	,, 17	,, 22	,, 20	,, 10	,, 20	,, 1	,, 21	,, 13
1937	Kulu .	April, 18	April, 23	April, 21	May, 11	May, 21	July, 2	July, 22	September, 22
	Kandhari	,, 15	,, 20	,, 18	,, 8	,, 18	June, 29	,, 19	,, 15
1938	Kulu .	April, 22	April, 27	April, 25	May, 15	May, 25	July, 3	July, 23	September, 25
	Kandhari	,, 19	,, 24	,, 22	,, 12	,, 22	June, 30	,, 20	,, 16
1939	Kulu .	April, 17	April, 22	April, 20	May, 10	May, 20	July, 6	July, 26	September, 23
	Kandhari	,, 14	,, 19	,, 17	,, 7	,, 17	,, 3	,, 23	,, 14

Insecticidal tests

During the past half a century, workers all over the world have been engaged in investigating suitable and effective insecticidal remedies against this important pest. Of the numerous insecticides consisting of stomach and contact poisons that have been tested by the various workers, McAllister and Van Leeuwen [1930] have listed no less than 284. These include various arsenicals, organic poisons such as nicotine, oils alone and in combination with arsenates of lead and calcium, nicotine sulphate, etc.; several stomach poisons other than arsenicals including fluorine compounds; and various stickers and spreaders. Although there is diversity of opinion among the workers regarding the effectiveness of the various insecticides used, a great majority of them still hold that lead arsenate is the most suitable and effective insecticide against the codling moth [Pettey, 1932] chiefly because of its low cost [Sherman III, 1936]. Spraying tests were carried out by us with a number of materials which were tested separately as well as in combination with others. Generally speaking, these insecticides, as is well known, can be divided into two classes—stomach poisons and contact sprays. The arsenicals and fluorides come in the first general group, while kerosene-oil, crude oil, nicotine sulphate (Black leaf '40') and fish oil fall in the second group. Each one of these was given a trial each year with a view to find out the most effective insecticide under Baluchistan conditions. The results obtained are recorded as follows :—

(1) *Lead arsenate*. Tests were carried out with this chemical using 4 lb. of lead arsenate powder to 100 gallons of water with casein as a spreader. When a full course of this spray was given, on the average it reduced the wormy fruit to 25 per cent in the Kulu and 26·5 per cent in the Kandhari variety. Spray residue from apples was removed by dipping in 1·5 per cent hydrochloric acid for two minutes and rubbing with a soft cloth.

The following materials were used in combination with lead arsenate in an attempt to increase its effectiveness or to add to the toxicity of the spray.

(*i*) ***Fish oil***. This was used with lead arsenate at the rate of one quart per 100 gallons of the spray on all cover sprays following a calyx spray with lead arsenate alone. The addition of fish oil resulted not only in a better type of coverage on the fruit but also in an increased deposit of lead arsenate. In addition, it had also an ovicidal value. Its application reduced on the average the wormy fruit to 16 per cent in the Kulu and 16·8 per cent in the Kandhari variety. Spray residue was removed by giving the fruit a dip in sodium silicate solution.

(*ii*) *Kerosene oil*. Experiments were conducted to test the efficacy of lead arsenate-kerosene oil combination. The spray was prepared according to the following formula :

Water	2 gallons
Ammonia (concentrated)	2·5 liquid ounces
Casein	4 ounces
Kerosene oil	8 gallons

Ammonia was first added to the water and then casein was dissolved in it after which oil was added slowly and mixed for 20 minutes. The mixture was churned thoroughly for about 20-30 minutes until the oil was thoroughly mixed. One gallon of this kerosene oil emulsion was used in 100 gallons of lead arsenate spray. This combination, when used in all thee fivsprays, reduced the wormy fruit on an average to 16·7 per cent in the Kulu and 17·7 per cent in the Kandhari variety. Although the addition of kerosene oil emulsion to lead arsenate increased the arsenic deposit on the fruit and besides acting as an ovicide, its application resulted in severely burning the leaves, along with partial defoliation of the trees. It had also the additional disadvantage of complicating residue removal.

(*iii*) *Crude oil*. This was combined with lead arsenate in the same proportion and the spray was prepared in the same way as the kerosene oil emulsion. This combination when used in all the five sprays, reduced the wormy fruit on the average to 18·5 per cent in the Kulu and 19·2 per cent in the Kandhari variety. Although this spray proved effective in controlling the worms by killing the eggs and young larvae, it was not superior to lead arsenate when used alone, as it resulted in severely burning the foliage. It had also the disadvantage of complicating residue removal.

(*iv*) *Nicotine sulphate* (Black leaf '40'). This was combined with lead arsenate at the rate of ¾ pint in 100 gallons of spray and was applied in all the five sprays. Although there was no foliage injury, it did not materially improve the worm control and the results obtained were almost equal to those got by the application of lead arsenate alone. On the average, it reduced the wormy fruit to 24·5 per cent in the Kulu and 26·2 per cent in the Kandhari variety. The spray residue was easily removed by dipping the fruit in 1·5 per cent hydrochloric acid solution.

Along with these tests, a few trees were kept as control where no spray was applied and on the average there was 78·5 per cent wormy fruit in the Kulu and 80 per cent in the Kandhari variety.

(2) *Calcium arsenate*. This chemical was selected because, next to lead arsenate, its cost, availability, compatibility with fungicides and stability appeared to be most promising of all suggested remedies. Experiments were

carried out using 3 lb. of calcium arsenate per 100 gallons of water with a small quantity of soap as a spreader. When a full course of this spray was given, on the average it reduced the wormy fruit to 27·2 per cent in the Kulu and 27·7 per cent in the Kandhari variety. These results indicated that calcium arsenate spray was not as effective as lead arsenate when used alone. No burning of foliage was, however, experienced. Spray residues from apples were easily removed by dipping them in one per cent hydrochloric acid solution.

Calcium arsenate has the advantage of being cheaper than lead arsenate and can be easily combined with a number of other materials, such as vegetable oils, mineral oils, fish oils, etc. The following materials were used in combination with calcium arsenate in an attempt to increase its effectiveness or to add to the toxicity of the spray.

(*i*) *Vegetable oil.* The vegetable oils tested were linseed, rape and castor oils. Experiments using calcium arsenate with these oils were carried out to find out the most effective combination amongst them. All mixtures were prepared with three pounds of calcium arsenate per 100 gallons of water and 1½ lb. of oil. The oils were churned well in water before adding calcium arsenate. Each combination was used in all the five sprays. The control obtained with linseed oil was in general a little better than that obtained with lead arsenate when used alone and on the average, it reduced the wormy fruit to 24 per cent in the Kulu and 24·5 per cent in the Kandhari variety. This combination had, however, the disadvantage of burning the foliage and affecting the colour of the fruit. Rape oil came next to linseed oil and on the average, reduced the wormy fruit to 24·5 per cent in the Kulu and 25 per cent in the Kandhari variety. This combination also burnt the foliage and affected the colour of the fruit. Castor oil gave poor results by reducing on the average, the wormy fruit to 30·5 per cent in the Kulu and 29·5 per cent in the Kandhari variety. There was, however, no foliage injury. Residues from apples sprayed with these combinations were easily removed by dipping in 1·5 per cent hydrochloric acid solution.

(*ii*) *Fish oil.* This was used with calcium arsenate at the rate of one quart per 100 gallons of the spray on all the cover sprays following a calyx spray with calcium arsenate alone. The combination was equal in efficiency to lead arsenate used alone and, on the average, reduced the wormy fruit to 25·2 per cent in the Kulu and 26 per cent in the Kandhari variety. Although little arsenic injury occurred early in the season on the trees sprayed with this combination, severe burning and yellowing of the foliage took place late in the season. Sodium silicate solution was used for removing the spray residue from apples.

(*iii*) *Kerosene oil.* When kerosene oil was used with calcium arsenate, a high deposit resulted, and the degree of control was better than lead arsenate spray. On the average, this spray, when applied in all five sprays, reduced the wormy fruit to 19·5 per cent in the Kulu and 20 per cent in the Kandhari variety. The kerosene oil emulsion was made with casein-ammonia in the same way as in lead arsenate-kerosene oil emulsion, but the quantity used was half a gallon of the emulsion to 100 gallons of the spray. This spray did not burn the foliage and further the residue was easily removed. Amongst all the calcium arsenate combinations, this has given the best results under our conditions.

Along with these tests a few trees were kept as controls where no spray was applied and on the average there was 78·5 per cent wormy fruit in the Kulu and 77·7 per cent in the Kandhari variety.

(3) *Cryolite sodium aluminium fluoride*). Trials were made with cryolite to find out its efficacy under our conditions. Used in all the five sprays at the rate of 4 lb. to 100 gallons of water, the results obtained were slightly better than lead arsenate used alone. On the average, its application reduced the wormy fruit to 24·5 per cent in the Kulu and 24·2 per cent in the Kandhari variety. Better results were, however, obtained when one pint of fish oil and a small amount of soap were added to the spray as they considerably improved the uniformity of the cryolite deposit. When cryolite-fish oil-soap are used, on the average this spray reduced the wormy fruit to 19 per cent in the Kulu and 19·7 per cent in the Kandhari variety. There was no foliage injury and the residue from apples was easily removed by dipping in 1·5 per cent hydrochloric acid to which 2 per cent boric acid was added.

A few trees kept as controls along with these tests gave on the average 79·5 per cent wormy fruit in the Kulu and 80 per cent in the Kandhari variety.

(4) *Kerosene oil-nicotine sulphate* (*Black leaf '40'*). Tests were made with this combination as a possible substitute for lead arsenate. The formula used was one gallon of kerosene oil emulsion prepared with casein-ammonia and one pint of nicotine shulphate (Black leaf '40') in 100 gallons of water. Experiments have shown that when this combination was used in all the five sprays, poor results were obtained. On the average, it reduced the wormy fruit to 38·5 per cent in the Kulu and 39·2 per cent in the Kandhari variety. Its effect was, however, very greatly increased if lead arsenate was applied on calyx and oil-nicotine combination on the subsequent cover sprays when, on the average, it reduced the wormy fruit to 16 per cent in the Kulu and 16·8 per cent in the Kandhari variety. The outstanding value of this combination was that it proved to be a triple-acting spray as it killed moths, eggs and larvae. The data on oil-nicotine spray as a whole indicate that it can be used to the best advantage on cover sprays where a lead arsenate spray has been given on calyx. It did not burn foliage and the residue from apples was easily removed by dipping first in sodium silicate solution and then in hydrochloric acid solution. On account of the high cost of the ingredients, it is however a costly spray. On control trees, the average wormy fruit produced in the Kulu variety was 80 per cent and in the Kandhari it was 80·5 per cent.

Summary of insecticidal tests

The effect of different sprays on the percentage of infestation is shown in Table V. It is clear from this table that lead arsenate-fish oil combination (series ii) and lead arsenate-kerosene oil emulsion-nicotine sulphate combination (series xv) have proved the most effective sprays, both reducing the wormy fruit on the average to 16 per cent in the Kulu and 16·8 per cent in the Kandhari variety. But comparatively speaking on account of the high cost of the ingredients of the latter combination, it cannot be used on a large scale. Next in effectiveness comes the lead arsenate-kerosene oil emulsion combination (series iii) reducing the wormy fruit to 16·7 per cent in the Kulu and 17·7 per cent in the Kandhari variety. But it has the disadvantage of resulting in

severe foliage burning, sometimes even in partial defoliation. Same was the case with the lead arsenate-crude oil emulsion combination (series iv). Cryolite-fish oil-soap combination (series xiii) also gave satisfactory results, reducing the wormy fruit to 19 per cent in the Kulu and 19·7 per cent in the Kandhari variety. The other combinations did not give satisfactory results. Taking into consideration every aspect of the spray, lead arsenate-fish oil combination has proved to be the best under our conditions.

Table V

Effects of sprays on the prcentage of infestation

Serial number	Treatment*	Kulu variety		Kandhari variety	
		Sound	Wormy	Sound	Wormy
i	4 lb. lead arsenate, Casein—Calyx, 4 Cover sprays .	75	25	73·5	26·5
ii	4 lb. lead arsenate—Calyx, 4 lb. lead arsenate, 1 qt. fish-oil—4 cover sprays	84	16	83·2	16·8
iii	4 lb. lead arsenate and one gallon kerosene oil emulsion —calyx, 4 cover sprays	83·3	16·7	82·3	17·7
iv	4 lb. lead arsenate and one gallon crude oil emulsion—calyx, 4 cover sprays	81·5	18·5	80·8	19·2
v	4 lb. lead arsenate and ¾ pt. nicotine sulphate—calyx, 4 cover sprays	75·5	24·5	73·8	26·2
vi	3 lb. calcium arsenate and soap—calyx, 4 cover sprays	72·8	27·2	72·3	27·7
vii	3 lb. calcium arsenate and 1½ lb linseed oil—calyx 4 cover sprays	76	24	75·5	24·5
viii	3 lb. calcium arsenate and 1½ lb. rape oil—calyx, 4 cover sprays	75·5	24·5	75	25
ix	3 lb. calcium arsenate and 1½ lb. castor seed—calyx, 4 cover sprays	69·5	30·5	70·5	29·5
x	3 lb. calcium arsenate and soap—calyx spray. 3 lb. calcium arsenate and 1 qt. fish oil—4 cover sprays	74·8	25·2	74	26
xi	3 lb. calcium arsenate and ½ gallon kerosene oil emulsion—calyx, 4 cover sprays	80·5	19·5	80	20
xii	4 lb. cryolite—calyx, 4 cover sprays . . .	75·5	24·5	75·8	24·2
xiii	4 lb. cryolite, 1 pt. fish oil and soap—calyx, 4 cover sprays	81	19	80·3	19·7
xiv	1 gallon kerosene-oil emulsion and 1 pt. nicotine sulphate (B. L. "40")—calyx, 4 cover sprays	61·5	38·5	60·8	39·2
xv	4 lb. lead arsenate—calyx spray. 1 gallon kerosene oil emulsion and 1 pt. nicotine sulphate (B. L. "40")—4 cover sprays	84	16	83·2	16·8

* Materials used in 100 gallons of spray

Traps

(*i*) *Light-traps*. Experiments were conducted to find out whether codling moths could be attracted to light or not. Six kerosene oil lamps were hung during the four years that the work was in progress every night throughout the season in unsprayed apple plots in two gardens at Quetta. The moths were not attracted to these lamps.

(*ii*) *Bait-traps*. The sprays are only effective if applied at the time when the maximum number of eggs of the two broods are laid in the orchard and are about to hatch. Such periods can be determined if we know when the moths emerge and when the largest number of them are present in the orchard. A

simple method of forecasting such periods is facilitated by a bait-trap, which attracts the moths in large numbers. The construction of such a trap described by Pettey [1932] is shown in Fig. 1, wherein instead of enamel bucket we used an enamel dish.

The following formula was used for the preparation of the bait :—

Molasses . .	one part
Water . .	nine parts
Yeast . . .	enough to start fermentation

Since it takes several hours for the fermentation to start, the baits were prepared in the morning and put out in pans in the sun. By evening they were ready for putting on the poles. Two-thirds of each pan was filled with the bait and refilling was done after every week.

Every year 10 bait-traps were placed near the two-thirds height on every fifth tree in an unsprayed apple plot at the Fruit Experiment Station, Quetta. During the season of 1936 a total of 1,088 moths were trapped in them, while their number during the seasons of 1937, 1938 and 1939 was 1,172, 1,093 and 1,105 respectively. Every year a few moths were caught in the beginning of April, but from about the middle of April, their number increased till about the middle of May, followed by a rapid decline. Again only a few moths were caught in the last week of June but the beginning of July registered an increase which continued until the middle of July when there was a decline. In the beginning of September, the use of traps was discontinued as no moths were attracted.

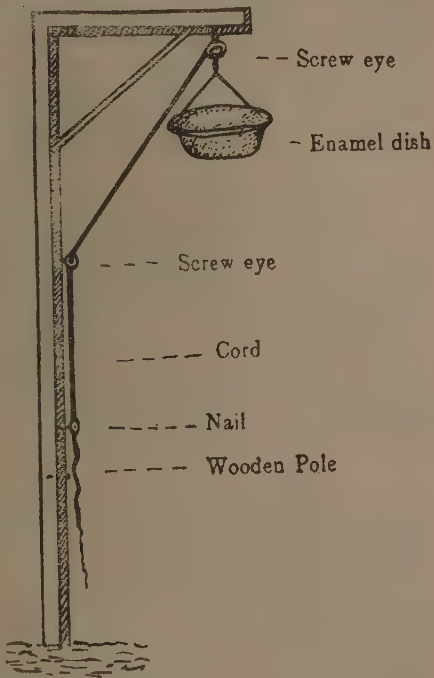

Fig. 1. A simple bait-trap for attracting codling moths (after Pettey)

The information collected from bait-traps helps in timing the spray dates. The actual dates are determined by corroboration with the seasonal activities of the insect. If there is a covering of the insecticide on the fruit during the period the adult moths are caught, most of the larvae hatching from the eggs laid by these moths will be poisoned.

Cost of spraying

The cost per 100 gallons of the most effective spray (4 lb. lead arsenate and 1 qt. fish oil) is Rs. 4-13 and the following gives the approximate expenses incurred per tree during the whole of the season :—

	As.	P.
Spraying materials	7	9
Labour	2	9
Bait-trap	1	6
	12	

The average yield of apples from a full-grown plant in the Quetta valley is about 200 lb. In an unsprayed tree, about 20 per cent of the fruits is healthy and therefore, marketable. A proper course of spraying increases the marketable fruit to 84 per cent. The average price of apples at Quetta is As. 1-6 per lb. and according to this price an unsprayed tree will bring about Rs. 3-12, while a sprayed one will fetch Rs. 15. Thus by incurring an expenditure of annas 12 per tree, the income can almost be raised to four times.

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BACTERIAL SOFT ROT OF TOMATOES CAUSED BY A SPORE FORMING ORGANISM

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(With Plates III and IV)

IN the summer of 1938 some tomato fruits of a large red variety (Pocha and Sons) on the college students' farm at Lyallpur were found to be attacked with a certain disease. The disease appeared in the form of an under-skin soft rot. In early stages the fruit showed a discolouration which with the advance of infection turned into a brown and wrinkled spot. In extreme cases the fruit was shrivelled and pulpy.

Some specimens of the fruit showing disease in early stages were brought to the laboratory and examined microscopically. The diseased tissue revealed the presence in large numbers of bacterial rods with round ends. With a view to isolate the causative organism platings were made from the infected tissue on nutrient agar of the following composition :

Beef extract . .	3 gm.
Peptone	5 ,,
Sodium chloride . . .	8 ,,
Agar agar	15 ,,
Distilled water . . .	1000 c.c.
*p*H	6·8

Two different types of colonies were noticed : (*i*) dull white spreading with irregular margin ; and (*ii*) circular, smooth creamy white with even margin.

Transfers were made from the two types but the growth on slants in both cases appeared to be similar. On microscopic examination too, both the cultures were found to be rods with rounded ends and central spores.

Infection trials

(1) Some fresh healthy semi-ripened tomato fruits were washed in clean water and the surface sterilized with mercuric chloride (1 : 1000). A portion of the surface was then wiped with alcohol and the fruits inoculated (with gentle needle pricks) in duplicate pairs with each of the cultures separately and in combination. These together with four controls (also pricked with sterilized needle) were incubated under aseptic conditions in sterilized petri dishes at room temperature (about 37°C.).

On the second day lesions became visible in the case of all the inoculated fruits ; these started as brownish spots and later became dark brown and

wrinkled. The infection was so virulent that after three days the fruit became pulpy and in another three days it was totally mashed up with a foul smelling exudate. None of the uninoculated fruits showed any sign of disease.

In the case of the infected fruits the diseased tissue was examined under the microscope and found to be full of rods in every case. The organism was reisolated from the diseased fruits and was found to be similar to the original pathogen in all cases.

(2) Another lot of healthy tomatoes was cleaned as above, a portion of the surface sterilized with alcohol and infected with the culture isolated under (1) above.

The disease appeared as before in the form of an underskin rot which spread rapidly and in four days the fruit was pulpy and mashed up. Plate IV fig. 2 shows the rot in different stages.

The organism

The organism is a rod with rounded ends measuring 0·75μ to 1μ by 1·25μ to 2·5μ, occurring singly. It is motile with peritrichic flagella and produces ovoid central spores measuring 0·75μ × 1·2μ, sporangia not bulged (Plate IV fig. 3). It is Gram positive.

Agar colonies :	Creamy white, raised, shining, amaeoboid or branching with crenate margin (Plate III Fig. 1). In very thick plates roundish flat colonies* were also noticed (Plate III fig. 2)
Agar slant :	Growth creamy white, shining, spreading at the bottom (Plate IV fig. 1)
Gelatine plate :	Colonies circular, growth whitish, liquefaction
Gelatine stab :	Stab visible by whitish growth along it. Liquefaction, crateriform
Broth :	Slightly turbid. Thin pellicle, coherent
Potato :	Growth, brownish, spreading, shining with blackening of the substrate
Litmus milk :	Not coagulated, colour discharged. Slight alkalinity. Separation of whey and settling of casein after prolonged incubation

Indol not formed
Nitrate not reduced
Starch not hydrolysed
Slight H_2S production
Acid from sucrose, dextrose, mannite, arabinose and glycerol
No acid from lactose, maltose, dulcitol and dextrin
No gas from carbohydrate broths
Ammonia produced from peptone
Optimum temperature 40°C. Growth limits 10° to 55°C.
Vegetative cells not killed at 79°C. for 10 minutes
Spores survive half an hour at boiling temperature

*Both the types of colonies were separately plated and were found to be capable of again segregating out by repeated trials. The cultures from these colonies were found to be identical morphologically and physiologically.

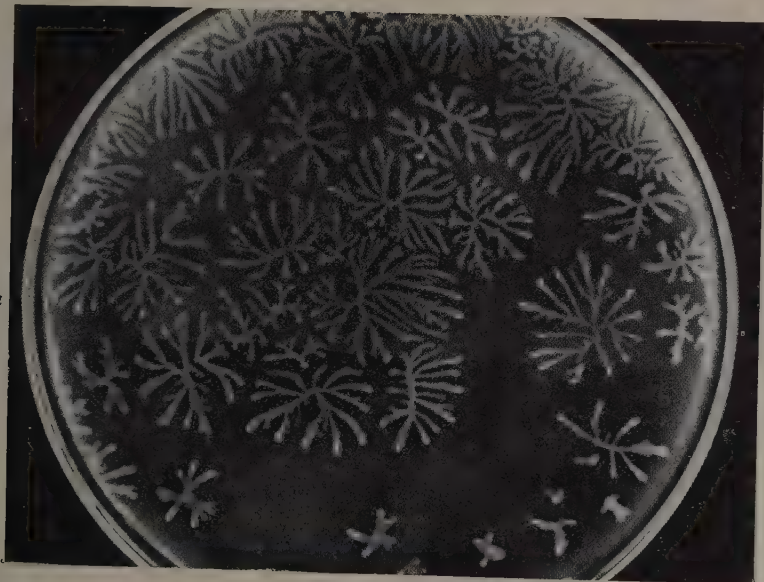

FIG. 1. Colonies on a thin agar plate

FIG. 2. Colonies on a thick agar plate

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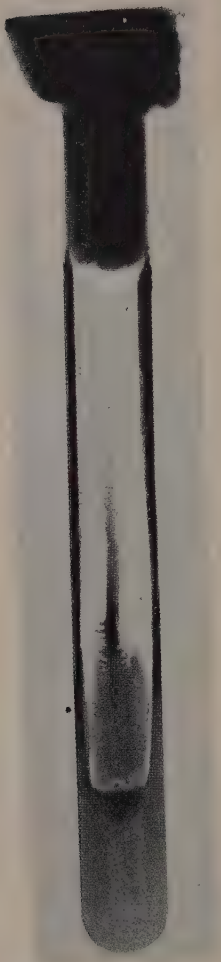

FIG. 1. Growth on an agar slant

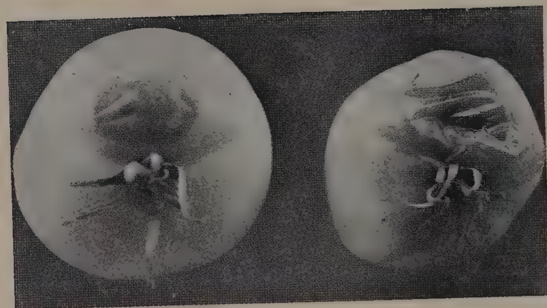

FIG. 2. The rot after three and five days

FIG. 3. The Organism showing central spores

Strict aerobe

NOTE

1. Basic-medium for the carbohydrate media had the following composition, one per cent of the required carbohydrate being added before sterilization in each case :

Beef extract	3 gm..
Peptone	5 ,, .
Distilled water	1000 c.c..
*p*H	7·0.

2. *Details of how tests were made*

a. *Reduction of nitrate*—The organism was inoculated in duplicate in tubes of nitrate broth and incubated at 30°C. Controls were also kept. These were tested occasionally with Greiss Ilosway's reagent for the presence of nitrite.

b. *Indol production*—Indol was tested in peptone water culture after an interval of 2 to 10 days with Ehrlich's reagent. (Para-dimethylamidobenzal-dehyde solution and potassium persulphate solution).

c. *Production of H_2S*—Lead acetate agar was inoculated in duplicate with the organism and incubated at 30°C. with two control tubes ; slight blackening of the inoculated tube showed the production of H_2S.

d. *Hydrolysis of starch*—Peptone broth containing 0·2 per cent soluble starch was employed for the purpose. A number of tubes of this medium were inoculated and kept under observation for a period of four weeks, and occasionally tested with iodine solution.

From the above recorded morphological and physiological study the organism apparently belongs to the family Bacillaceae, genus *Bacillus* and is mesophilic. It appears to belong to the *Bacillus subtilis* group but the cultural characteristics do not agree completely with any of the known species.

Hence a new species name *Bacillus fructodestruens* is proposed formally.

Bacillus fructodestruens (Madhok and Fazal-ud-Din) sp. nov.

Rods :	0·75-1·0 × 1·25-2·5 microns, occurring singly, motile with peritrichic flagella
Spores :	Central, ovoid, 0·75 × 1·2 microns, not bulging the sporangium
Gram stain :	Positive
Agar colonies :	Creamy white, raised, shining amaeoboid or branching, crenate margin. Roundish in thick plates
Agar slant :	Growth creamy white, shining, spreading at the bottom
Gelatine plate	Colonies circular, growth whitish, liquefaction
Gelatine stab :	Stab visible by whitish growth along it. Liquefaction, crateriform
Broth :	Slightly turbid. Thin pellicle, coherent
Potato :	Growth, brownish, spreading, shining with blackening of the substrate
Litmus milk :	Not coagulated, colour discharged. Slight alkalinity. Separation of whey and settling of casein after prolonged incubation

Indol not formed

Nitrate not reduced

Starch not hydrolyzed
Slight H_2S production
Acid from sucrose, dextrose, mannite, arabinose and glycerol
No acid from lactose, maltose, dulcitol and dextrin
No gas from carbohydrate broths
Ammonia produced from peptone
Optimum temperature 40°C. Growth limits 10° to 55°C.
Vegetative cells not killed at 70°C. for 10 minutes
Spores survive half an hour at boiling temperature
Strict aerobe
Source : Isolated from diseased tomato fruits
Habitat : Not studied

Bacterial soft rot of tomato has previously been recorded by Brierley [1928] as caused by artificial infection with *B. phytophthorus* and *B. aroideae*, now named *Erwinia phytophthora Appel*, and *Erwinia aroideae* Townsend, and classed in *Entrobacteriaceae* Rahn [Bergey 1939]. Brown [1926] has reported the production of stem-end and centre rot of tomato by artificial infection with six different non-sporing bacteria, viz. *Bact. malva cearum* EFS., *Bact. marginale* Brown, *Bact. campestre* EFS., *Bact. tumefaciens* Smith and Townsend ; *Bact. savastanoi* EFS., and *Bact. viridilividum* Brown. Both the workers, however, failed to produce the disease with any spore forming organism.

Pathogenesis

Having established that the spore forming organism isolated by us was capable of causing soft rot in healthy fruits, it was considered desirable to try infection trials on fruits actually borne on the plants.

The first trial was made at the end of January when fruits on two plants grown in pots were infected with the causative organisms with gentle needle pricks. No signs of the disease appeared even after three weeks. The trials were repeated in June when the organism successfully produced the infection which appeared in the form of brownish lesions after two days. These lesions became dark brown and wrinkled after five days.

This established the fact that the organism is a positive parasite but that it works only in the summer season when the surrounding temperature is high.

Note

It is generally believed that spore bearing bacteria do not cause plant diseases. In view of this the culture of the causative organism in this case was subjected to the following treatments to ensure its purity :

Repeated platings and reisolations of the culture were done. Two loopfuls of this selected sporing culture were inoculated in 10 c.c. of sterile water contained in a test tube. The inoculum was dispersed by gently rotating the tube in the palms of hands. Every precaution was taken both during inoculation and shaking of the inoculum to avoid contaminating the empty portion of the tube.

The inoculated tube was immersed in water-bath up to the plugged portion and the water brought to boil. After 10 minutes exposure at boiling temperature the culture was plated on nutrient agar and the organism reisolated from a characteristic plate colony. This culture when used for infection trials was found to be as virulent as the mother culture tried before. It developed spores on keeping.

The presence of any non-spore forming organism in this culture cannot be suspected after such a drastic heat treatment. This establishes the fact that the causal organism in this case is a spore forming bacillus.

Control

No attempts were made to study control measures that would check the progress of the disease because the pathogen is so virulent and the fruit so perishable that there is very little chance of recovery. The fruit once infected shows signs of the rot in two days and is totally mashed up within six days. Since the disease is only found on the fruit and on no other part of the plant, it is likely that the infection occurs in wounds caused by insects.

Summary

A soft rot of tomato fruits caused by a spore forming organism has been recorded. The disease appears in the form of an underskin rot which spreads rapidly and in four to six days the fruit is pulpy and mashed up. Morphological and cultural characteristics of the causative organism have been studied. The organism is a virulent pathogen and works best at high temperatures, viz. 98°-104°F.

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AVAILABILITY OF PHOSPHATES IN ALKALINE AND CALCAREOUS SOILS

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ONE of the main problems that confronts the agricultural chemist is the estimation of the requirements of a given soil for specific plant food materials. For various reasons even the most modern methods adopted for soil analyses fail to give in many cases the requisite information. Hence, from time to time, attempts have been made to attack the problem indirectly, and use the living plant as an analytical agent [Neubaner, 1925; Hardy, Hanschell and Amoroso-Centend, 1938]. The method consists in taking a particular plant and growing it on a given soil under controlled conditions, and then determine in its ash content the proportions of various mineral constituents including such plant food materials as nitrogen, potash and phosphoric acid. Any deviations from the normal in these proportions may then be taken as indicating deficiency or excess of the same constituent in the soil, and therefore, the need or otherwise of specific manuring in that direction. From this point of view, a number of investigations on the availability of phosphate in *bari* soil (alkaline soil) under controlled conditions have been carried out and the results are reported in this paper.

It has been stated elsewhere [Singh and Nijhawan, 1932] that the infertility of *bari* soil is mainly due to a deficiency of exchangeable calcium, which can be made good with the help of soluble calcium salts. It has also been observed [Singh and Nijhawan, 1936] that the physical properties of *bari* soil adverse to plant growth are greatly modified when the exchangeable calcium of the soil attains a value of 5·0 m.e. or more. Therefore, the low yields of wheat grain in the data already reported and reproduced below (Table I) for the sake of convenience could not be ascribed to either a deficiency of exchangeable calcium or any adverse physical conditions, but due to lack of some important plant food material.

TABLE I

Yield of wheat in lb. from plots treated with calcium salts

	1929-30		1930-31		1931-32		1932-33		1933-34	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Calcium chloride at two tons per acre from 1927-30	288	699	767	1206	1160	1975	1438	2178	1439	3000
Gypsum at two tons per acre from 1927-30	226	411	267	417	769	1327	1726	2589	1336	2734

Farmyard manure was applied in the year 1930 for the first time at the rate of 15 tons per acre.

From the above data it will be seen that with the application of farmyard manure in 1930, there was a sudden increase in the yield of wheat crop, amounting to almost double of what was obtained in 1929. Subsequent applications of manure further improved the yields and a maximum was attained in 1932-33. The ratio of straw to grain decreased with the applications of farmyard manure, and it occurred to the authors that increased yields of grain might be due to an increased availability of phosphates rather than nitrogen. Breazeale and McGeorge [1932] observed that due to a deficiency of carbon dioxide in the calcareous soils nutritional disorders set in, and that an addition of manure to the black alkali soil evolved carbon dioxide which rendered more phosphate available to the crop. Therefore, in order to find out whether the application of calcium salts employed in the process of reclamation of *bari* soil with and without the addition of farmyard manure affected the availability of phosphoric acid, the following experiments in pots were arranged :

EXPERIMENT NO. 1

The experiment was carried out on *bari* soil from the Montgomery Agricultural Station where the field experiments referred to above had been in progress for a number of years. A composite sample of the soil on analysis gave the following results (Table II) :

TABLE II

Analysis of 'bari' soil

(Per cent on air-dry soil)

I *Mechanical analysis*

Clay	Silt	Fine sand	Coarse sand	*Kankar*
20·16	37·23	41·11	0·72	0·35

II *Chemical analysis*

Insoluble residue	Soluble silica	Fe_2O_3	Al_2O_3	CaO	MgO	P_2O_5	K_2O	Na_2O	Organic matter	Nitrogen
76·85	0·11	4·93	8·54	3·08	1·45	0·25	1·16	0·87	0·28	0·03

III *Available analysis*

Phosphorus (P_2O_5)	Potassium (K_2O)
0·10	0·09

IV *Exchangeable bases* (Milligram-equivalents)

Calcium as Cs	Magnesium as Mg	Sodium as Na	Potassium as K
1·53	1·30	9·39	1·05

From the finely powdered and properly mixed bulk sample 12,000 gm. of the soil were put in each pot. Thus, altogether 12 pots were prepared, each treatment being given in duplicate. After thoroughly leaching the soil to remove its excess of soluble salts, the following treatments were given :

Treatments

I. Calcium chloride with and without farmyard manure . . . . 6·66 gm. per pot

II. Gypsum with and without F. Y. M. (calculated on basis of calcium in $CaCl_2$) . . . . 10·32 gm. per pot

III. Normal soil with and without F. Y. M.

Farmyard manure was added at the rate of 15 tons per acre. Before sowing wheat soil samples were obtained, and available phosphorus determined in them by Dyer's citric acid method [1894] and Das' potassium carbonate method [1926]. The results of analysis are reported in Table III.

TABLE III

Availability of phosphates with citric acid and potassium carbonate methods

Description	Name of method	P_2O_5 as percentage on air-dry soil
1 *Bari* soil untreated	(*a*) Citric acid	0·1234
	(*b*) K_2CO_3	0·0013
2 *Bari* soil treated with calcium chloride	(*a*) Citric acid	0·1252
	(*b*) K_2CO_3	0·0018
3 *Bari* soil treated with calcium chloride and farmyard manure	(*a*) Citric acid	0·1399
	(*b*) K_2CO_3	0·0061
4 Normal soil	(*a*) Citric acid	0·0345
	(*b*) K_2CO_3	0·0014

From the data presented in Table III it will be seen that by both the methods the *bari* soil appeared to be rich in available phosphorus, which is even more than that in the normal soil. On treatment with calcium salts and farmyard manure the phosphate content increased slightly. Similar results were obtained with potassium carbonate method as in the case of citric acid. Thus, it will be observed that according to chemical methods of soil analysis the *bari* soil does not appear to be deficient in available P_2O_5, but on the other hand, the phosphate content by Dyer's method is as high as hydrochloric acid-soluble phosphate present in some of the fertile soils of the Punjab. For the sake of comparison the results of acid-soluble P_2O_5 from some of the good soils in the Punjab are given in Table IV.

TABLE IV

Total and available phosphates in Punjab soils

(Percentage on air-dry soil)

(P_2O_5)

Description	Hydrochloric acid-soluble	Citric acid-soluble
1 *Bari* soil	0·256	0·100
2 Lyallpur (Agricultural Farm)	0·196	0·054
3 Gujranwala (Kala Shah Kaku)	0·174	0·059
4 Kangra (Baijnath)	0·079	0·029
5 Montgomery	0·263	0·063
6 Rohtak	0·118	0·029

Hydrochloric acid-soluble as well as citric acid-soluble phosphorus is greater in the *bari* soil than in the normal soils. These results clearly show that the chemical methods of soil analysis in the case of alkaline soil do not

give a true indication of the availability of phosphorus, but give abnormally high values. On maturity the entire wheat crop was removed, dried, weighed, ashed and analysed for various mineral constituents according to tentative and official methods of the Association of Official Agricultural Chemists. The results are reported in Table V.

TABLE V

Crop analysis : yield and composition of wheat crop affected by calcium salts and F. Y. M.

Treatments	Iron Fe_2O_3	Calcium CaO	Magnesium MgO	Phosphate P_2O_5	Potassium K_2O	Yield per pot
I Set—						
Calcium chloride	0·1697	1·99	0·280	0·0911	1·84	10·3
Gypsum	0·0800	1·77	0·390	0·1359	1·90	68·4
Normal soil	0·0893	0·94	0·385	0·2069	2·66	10·36
II Set—						
Calcium chloride and F. Y. M.	0·1699	0·83	0·235	0·5037	1·78	17·7
Gypsum and F. Y. M.	0·1954	0·57	0·285	0·3503	1·38	14·3
Normal soil and F. Y. M.	0·2194	0·47	0·296	0·4817	2·59	11·2

A reference to Table V shows that in the first set, where chemicals alone are employed, the amount of P_2O_5 removed in the case of soil treated with calcium salts is much less than in the case of normal soil. The amount of K and Mg removed is also less, but the variation is not of the same order. On the other hand, the amount of Ca removed is much greater than that of the normal soil. In the second set, with the addition of F. Y. M., the amount of P_2O_5 removed in all cases is much greater than in the first set, the percentage increase being greater in the case of soils treated with calcium salts. The same is the case with iron which also records a great increase with the addition of F. Y. M. Calcium, on the other hand, shows a tremendous decrease, while Mg and K only record a slight decrease. These results also show that the crop removed from calcium chloride-treated soil contains greater amount of P_2O_5 and calcium than that removed from gypsum-treated soil. These findings are in accordance with the yield data which are greater in case of calcium chloride pots than those treated with gypsum.

EXPERIMENT No. 2

The results from the first experiment suggested that the uptake of calcium and phosphates, and more especially the latter as revealed by the crop analyses, depended on the nature of calcium salts used in the reclamation process. The lower yield in case of gypsum when F. Y. M. is added may be due to less availability of phosphorus for the growth of plants. Gypsum being a comparatively cheap chemical is likely to find more use for the reclamation of *bari* soil, and it seemed necessary that its effect on the availability of phosphorus which appeared to operate as a limiting factor in the crop production in this type of soil, should be investigated. With this end in view, a pot experiment was arranged and both the calcium salts were added in increasing doses. Calcium chloride was added at the rate of 0·5, 1·0, 2·0, 4·5, and 7·5 tons per acre and gypsum was added in equivalent amounts. Farmyard manure

was added in each pot at the rate of 15 tons per acre. Each treatment was arranged in duplicate, and wheat crop sown. The ash analyses of the crop removed from these pots are given in Table VI.

TABLE VI

Crop analysis : composition and yield of wheat crop affected by varying doses of calcium salts

Treatments	Iron Fe_2O_3	Calcium CaO	Magnesium MgO	Phosphate P_2O_5	Potassium K_2O	Nitrogen N	Yield in gm. per pot
1 Calcium chloride at ½ ton per acre	0·2277	0·4686	0·3535	0·5217	2·65	...	5·8
2 Gypsum at 0·77 ton per acre	0·1294	0·3623	0·3451	0·3036	1·75	...	5·6
3 Calcium chloride at 1 ton per acre	0·2014	0·5116	0·2877	0·6288	2·39	1·47	7·2
4 Gypsum at 1·55 ton per acre	...	0·2970	0·3964	0·5345	2·33	1·39	3·0
5 Calcium chloride at 2 tons per acre	0·3023	0·4069	0·3284	0·5967	2·95	1·33	7·3
6 Gypsum at 3·1 tons per acre	0·3895	0·4512	0·3623	0·5662	3·16	1·36	5·3
7 Calcium chloride at 4·5 tons per acre	0·3134	0·6347	0·3814	0·7097	3·74	...	6·4
8 Gypsum at 7·5 tons per acre	0·3039	0·3868	0·2681	0·5416	2·32	1·36	7·6
9 Calcium chloride at 7·5 tons per acre	0·2321	0·5371	0·2559	0·6580	2·77	1·39	8·5
10 Gypsum at 11·66 tons per acre	0·2633	0·6096	0·3741	0·5429	2·78	1·33	8·1

Up to a certain level which is attained when gypsum and calcium chloride are applied at the rate of 3·1 and 4·5 tons per acre respectively, there is an increase in the mineral matter of all the ingredients with increasing doses of calcium salts, but after that level further increase in the doses of calcium salts bring about generally a decrease in the mineral matter removed. Further, it is observed, that more calcium and P_2O_5 is removed by plants grown in the calcium chloride-treated soil than from the gypsum-treated soil, but the increase is more marked in the case of P_2O_5 than in the case of calcium. Maximum amount of P_2O_5 removed was 0·7097 per cent by plants grown on calcium chloride-treated soil, while the maximum amount removed by the plants from the gypsum-treated soil was only 0·5662 per cent. These results again show that the treatment of *bari* soil with calcium salts renders more P_2O_5 available, the increase in the case of calcium chloride being greater than in the case of gypsum. Total nitrogen was also determined in the crop, but the results do not show any effect of the chemicals on the amount of nitrogen removed by the crop.

EXPERIMENT No. 3

While studying the effect of different cations saturating the soil exchange complex on the physical properties of *bari* soil, the authors [1936] observed that such soils were able to support a crop of wheat if sodium of the exchange complex was replaced by magnesium, manganese or potassium. The soil in its original condition contains 3·08 per cent of calcium oxide which is almost entirely present as calcium carbonate, and if this calcium could be made to react with the soil, it will replace sodium from the exchange complex and thus bring about an improvement of the soil. While preparing ammonium

clays by leaching the soil with ammonium salt solutions the authors [1936] observed that only half the sodium was replaced with ammonium ions, the remaining half being replaced by calcium ions. The reason appeared to be that calcium carbonate is soluble in ammonium salts, and in that manner is able to react with the sodium of the exchange complex. Similarly, calcium carbonate can be rendered soluble by treating the soil with acids thereby utilizing calcium for the exchange reaction. In order to determine the effect of other salts and acid treatment tried in the reclamation of *bari* soil on the availability of phosphate in this soil, an experiment with the following treatments was arranged :

1 Calcium chloride at 4·5 tons per acre with and without farmyard manure
2 Magnesium nitrate with and without farmyard manure
3 Manganese chloride with and without farmyard manure
4 Potassium nitrate with and without farmyard manure
5 Ammonium sulphate at 820 lb. per acre with and without farmyard manure
6 Hydrochloric acid just sufficient to liberate 0·1 per cent of calcium with and without farmyard manure.

Magnesium nitrate, manganese chloride and potassium nitrate were added in equivalent amount to calcium chloride at the rate of 4·5 tons per acre. The pots filled with 12,000 gm. of the soil were flooded and washed to remove the excess of water-soluble salts. After the treatments the pots were left over for a period of five months during which interval they were occasionally watered and stirred. Farmyard manure was added at the end of this period and crop sown a fortnight later. Results of crop analyses and yield data are given in Table VII.

TABLE VII

Crop analysis: composition and yield of wheat crop as affected by treatment with various salts (with and without F. Y. M.)

Treatments	Iron Fe_2O_3	Calcium CaO	Magnesium MgO	Phosphates P_2O_5	Potassium K_2O	Nitrogen N	Yield in gm. per pot
1 Calcium chloride without F. Y. M.	0·145	0·486	0·241	0·102	1·012	...	3·4
2 Calcium chloride with F. Y. M.	0·338	0·402	0·242	0·282	0·544	1·39	6·9
3 Magnesium nitrate without F. Y. M.	0·398	0·529	0·595	0·167	2·112	...	4·4
4 Magnesium Nitrate with F. Y. M.	0·347	0·408	0·627	0·280	1·832	...	6·10
5 Manganese chloride without F. Y. M.	0·360	0·604	0·319	0·164	1·110	...	2·3
6 Manganese chloride with F. Y. M.	0·380	0·650	0·391	0·548	2·797	...	6·0
7 Ammonium sulphate at 10 md. per acre without F. Y. M.	0·296	0·659	0·316	0·191	1·579	1·78	3·9
8 Ammonium sulphate at 10 md. per acre with F. Y. M.	0·232	0·441	0·310	0·405	2·849	1·52	8·1
9 Potassium nitrate without F. Y. M.	0·868	1·340	0·484	0·259	13·630	...	1·4
10 Potassium nitrate with F. Y. M.	0·620	0·764	0·362	0·340	5·260	...	3·5
11 Hydrochloric acid without F. Y. M.	0·207	0·609	0·320	0·209	1·545	...	4·8
12 Hydrochloric acid with F. Y. M.	0·201	0·388	0·321	0·296	1·813	1·42	8·3

The results obtained show that though the availability of phosphates depends on the nature of the salts applied, yet the application of farmyard manure in all the cases increased the amount of phosphate in the crop. With increase in phosphate, there was a corresponding increase in the yield of the crop, and the yields from the pots treated with farmyard manure were nearly double of those which did not receive any application of it.

The application of nitrogenous fertilizers alone in no way increased the yields. Nitrogen removed by the crop from the soil-treated with ammonium sulphate alone was undoubtedly more but it had no effect on the yield of the crop. The yields from the pots treated with ammonium sulphate and potassium nitrate were not more than those from the pots under other treatments, but these became more than double by the application of farmyard manure. Phosphates were removed comparatively in large amounts from all the pots treated with other salts than those treated with calcium salts.

With the application of farmyard manure though the amount of phosphates in the crop increased yet there was a decrease in all other minerals, decrease being more in the case of iron and calcium than magnesium, which slightly decreased or remained more or less constant. The behaviour of potassium was however different. Potassium in the crop removed from the pots treated with calcium, magnesium and potassium salts showed a decrease, but that removed from the pots treated with manganese chloride, ammonium sulphate and hydrochloric acid showed a definite increase, the increase being more in the crop got from the pots treated with the first two salts than those treated with hydrochloric acid.

Crops removed a comparatively larger amount of the salt with which the soil is treated, except in the case of soil treated with calcium salts where the amount of calcium removed was more or less the same or even less than that removed by the crops grown in the soil treated with other salts. Potassium was removed in very large quantities (13·630 per cent), but its amount greatly decreased (5·24) when farmyard manure was added in addition to the potassium salt. Thus, the luxury consumption of potassium manures can be greatly decreased by the addition of farmyard manure.

Conclusions

1. Chemical methods do not give correct information regarding the availability of phosphorus in alkaline calcareous soils. Acidic extracting agent like citric acid used in Dyer's method yields large amount of phosphate. Phosphate thus found is much higher than usually found in calcareous soils.

2. Phosphate removed by wheat crop from an alkaline soil reclaimed by the application of calcium salts is much less than by the crop grown on a normal soil.

3. Application of farmyard manure to such a soil increases the absorption of phosphate by the crop, which becomes as high as in a crop raised on a normal soil.

4. Crop removed from a calcium chloride-treated soil contains more phosphorus and calcium than the crop grown on a gypsum-treated soil.

5. With increasing doses of calcium salts, there is an increase in the amount of phosphate removed by the crop, increase being more in the case of calcium chloride-treated soil than in the case of gypsum-treated one. Maximum

amount of phosphate removed by the crop from the soil treated with calcium chloride and gypsum was 0·7097 and 0·5662 per cent respectively.

6. Salts other than calcium which may be used for the reclamation of alkaline soils increase the amount of phosphates removed by the crop, but its quantity is much less than that found in a normal wheat crop. On the other hand, application of farmyard manure in addition to these treatments brings about a great increase in the phosphorus content of the crop.

7. Application of nitrogenous fertilizers does not increase the yield, but when farmyard manure is also added, the yields are doubled. Application of farmyard manure, however, does not increase the nitrogen content of the crop.

8. The nature of cations in the exchange complex affects the availability of phosphorus. A calcium soil possesses less available phosphorus than soils containing other cations.

9. Plants remove in larger amounts the cation with which the soil complex is saturated, excepting calcium, which is removed more or less in the same quantity as from a soil saturated with other cations. Potassium is removed in much larger quantity as compared to other cations.

10. With the application of farmyard manure though there is increase in the amount of phosphate removed there is a decrease in other minerals such as calcium, magnesium and iron.

11. When farmyard manure is added to soils treated with salts of potassium, magnesium and calcium, the potassium removed by the crop from these soils decreases.

12. In the case of alkaline calcareous soils crop analyses give better indication of the availability of minerals, especially phosphorus.

Summary

The results corroborate the findings of other workers that the chemical methods of analyses do not give correct information regarding the availability of phosphates in alkaline calcareous soils. Crop analyses give better results.

The availability of phosphates and other minerals as affected by the different salts with and without F. Y. M. in the reclamation of *bari* soil has also been investigated.

With the application of calcium chloride the availability of phosphorus in the presence of farmyard manure is increased.

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FRACTIONATION OF SOIL PHOSPHORUS

II. CHEMICAL NATURE OF THE PHOSPHORUS FRACTIONS

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In the work reported previously [Ghani, 1942], $N/2$ acetic acid, $N/4$ sodium hydroxide and $2N$ sulphuric acid were used as extractants in a method of fractionation of soil phosphorus and the conditions of extraction were critically examined. The inorganic phosphorus fractions dissolved by acetic acid, sodium hydroxide and sulphuric acid in succession were tentatively supposed to be non-apatitic calcium phosphates, iron and aluminium phosphates and apatite phosphates respectively. But before any hard and fast conclusion can be drawn regarding the chemical nature of the different fractions it is necessary that the solubility of known phosphorus compounds in these solvents should be known and the solubility determinations should be made under the same conditions as are adopted in the fractionation. Until accurate and independent methods for the determination of the individual phosphorus fractions in soil are known this mode of attack will remain to be the only way in deciding the point in question.

Solubility study of inorganic phosphorus compounds

Many attempts have been made in the past to deduce the probable nature of the acid and alkali soluble phosphates of soil by studying the solubility of common phosphatic materials in different solvents and in solutions having different pH values. Fraps [1911] found that ammonia dissolved phosphoric acid from phosphates of iron and aluminium more readily than from phosphates of lime. He believed that ammonia extracted from soil the organic phosphorus and iron and aluminium phosphates. Gaarder [1930] studied the solubility of iron, aluminium, calcium and magnesium phosphates in solutions of various pH values. He found that ferric phosphate had its point of minimum solubility near pH 2. With still more acid conditions there was complete solubility while a change towards the alkaline side resulted in the hydrolysis of iron phosphates. Aluminium phosphate reacted in much the same way, the point of minimum solubility being at about pH 4. Calcium phosphate was precipitated between pH 6 and pH 7 and did not hydrolyse at higher pH values. The work of McGeorge [1935] also showed a similar relation between pH and solubility.

Williams [1937] found that the mineral calcium phosphates had a very low solubility and the iron and aluminium phosphate minerals a high solubility

in 5 per cent sodium hydroxide. Dean [1938] got similar results with both sodium hydroxide and sodium carbonate. Both the authors extracted the materials by digesting at 100°C.

Experimental

The solubility of mono-, di- and tricalcium phosphates, apatite, ferric phosphate (basic and normal) and aluminium phosphate each in $N/2$ acetic acid, $N/4$ sodium hydroxide and $2N$ sulphuric acid were determined. The extractions were done by shaking 10 mg. of the substance at room temperature for two hours in a mechanical shaker with appropriate volume of each of the solvents. Phosphorus determinations in the extracts were made by the colorimetric method of Deniges as improved by Truog and Meyer [1929]. The results showing the solubility in mg. P_2O_5 as well as in per cent of the total P_2O_5 appear in Table I.

TABLE I

Solubilities of known phosphorus compounds in acetic acid, sodium hydroxide and sulphuric acid

Substances	Calcium phosphate (monobasic)	Calcium phosphate (dibasic)	Calcium phosphate (tribasic)	Apatite	Iron phosphate (normal)	Iron phosphate (basic)	Aluminium phosphate
Mg. P_2O_5 taken (10 Mg. substance)	5·63	4·61	4·58	3·80	4·77	2·00	5·82
Mg. P_2O_5 sol. in acetic acid (250 c.c.)	5·62	4·61	4·22	2·40	0·30	0·24	2·8
Per cent P_2O_5 soluble	100	100	92	63	6	12	48
Mg. P_2O_5 sol. in $N/4$ NaOH (300 c.c.)	4·00	1·32	0·12	Trace	4·0	1·6	3·8
Per cent P_2O_5 soluble	71	29	3	...	84	80	65
Mg. P_2O_5 sol. in $2N$ H_2SO_4 (250 c.c.)	5·74	4·60	4·60	3·40	3·90	2·00	4·40
Per cent P_2O_5 soluble	100	100	100	90	82	100	76

In $N/2$ acetic acid both mono- and dicalcium phosphates are completely soluble while tricalcium phosphate is slightly less soluble. About two-third of the apatite phosphorus has been dissolved in it. This high solubility of apatite phosphorus in dilute acetic acid may be due to the fact that the apatite minerals usually contain some soluble tricalcium phosphate. This is more probable because the residual phosphorus in the sample was sparingly soluble in $N/2$ acetic acid, and could not be dissolved by repeating the extraction several times. Solubility of the two iron phosphates is extremely low in acetic acid ; it comes to about 0·1 mg. P_2O_5 per 100 c.c. of the solvent used. Aluminium phosphate is, on the other hand, more soluble than iron phosphates. Gaarder [1930] pointed out that the minimum solubility of aluminium phosphate was at a pH of 4 but the pH of the acetic acid used here was near about 3 and hence latter may dissolve more of the phosphates. But again McGeorge [1935] comparing the solubility of iron and aluminium phosphates found that 4 was not the optimum pH for aluminium phosphate and that it was much more soluble than iron phosphate at that pH. On the whole it would thus seem that acetic acid will extract from soil mainly mono- and

dicalcium phosphates and non-apatitic tricalcium phosphates whereas other types of soil phosphorus would mostly remain in the residue. Even if any other phosphorus compound such as aluminium phosphate be dissolved, the amount would be comparatively small.

It is further seen that the solubility of the monobasic calcium phosphate is about 71 per cent in sodium hydroxide and that it rapidly falls off as the basicity of the substance increases. Ultimately the solubility is almost nil in the case of the mineral. On the other hand, the phosphates of iron and aluminium are highly soluble though the aluminium compound is comparatively less soluble. This would show that if the alkali extraction of the soil is done after an acetic acid extraction, the alkali will dissolve iron and aluminium phosphates only (besides organic phosphorus). This is because mono-, di- and tricalcium phosphates had already been removed from the soil by the acid pretreatment and apatite phosphorus is insoluble in alkali. In $2N$ sulphuric acid all the substances except aluminium phosphate are highly soluble. The solubility of apatite is about 90 per cent and it may be assumed that the phosphates of apatite nature that remain unaffected by the previous acid and alkali extractions would be dissolved by $2N$ sulphuric acid in the last treatment. The descending order of solubility of the calcium phosphates with increasing alkalinity or decreasing acidity shows the completely differrent behaviour of iron and aluminium phosphates. They first decrease reaching a minimum and then increase with increase in pH.

From what has been said above it would seem that alternate extraction with acetic acid, sodium hydroxide and sulphuric acid may be made a reasonable basis for the fractionation of the soil phosphorus into groups of known substances. To test the point further, mixtures of soil and known phosphorus compounds were fractionated by the method already described by one of the authors [Ghani, 1942]. Such a fractionation will show the extent of recovery of the various substances added and the fractions in which they are recovered and would therefore give valuable information regarding the validity of fractionation.

Fractionation of mixtures of soil and known phosphatic compounds

Two soils were selected one of which was nearly neutral in reaction (pH 7·3) and the other highly acid (pH 4·5). If there be any subsidiary reaction between the added phosphorus and the other soil constituents, it would be reflected in the behaviour of the two soils having different pH.

One gram samples of the two soils were thoroughly mixed with 10 mg. of the following substances: mono-, di- and tricalcium phosphates, apatite, ferric phosphate and aluminium phosphate. The mixtures were moistened with water to cause more intimate mixing of the substance and the soil, air dried after a few hours and then fractionated. A control sample without any phosphatic material in it was similarly treated and fractionated exactly in the same way. The results of the fractionation are shown in Table II.

The column 'added P_2O_5 recovered' has been obtained by subtracting the total of the control from the sum of the three fractions determined in the mixtures.

Taking into consideration the inevitable errors in adding up so many fractions, it appears that the recovery of the added phosphorus is almost 100

per cent in all the mixtures excepting the one containing aluminium phosphate. This is true for both the soils. Aluminium phosphate behaves rather abnormally as the whole of its phosphorus cannot be accounted for by the three fractions. By a reference to Table I it is seen that its solubility in sodium hydroxide as well as in sulphuric acid is much lower than that of the other substances, which means that a part of its phosphorus is present in a highly insoluble form. If, however, the recovery is expressed as per cent of the soluble phosphorus added, instead of the total phosphorus added, it amounts to about 92 and 97 per cent in the two soils.

TABLE II

Fractionation of a mixture of soil and various inorganic phosphorus compounds

Substance mixed with soil	P_2O_5 added (mg.)	Acetic acid sol. P_2O_5 (mg.)	Alk. sol. inorg. P_2O_5 (mg.)	Sulphuric acid sol. P_2O_5 (mg.)	Total P_2O_5 dissolved (mg.)	Added P_2O_5 recovered (mg.)	Per cent P_2O_5 recovered
Soil—Jessore, *p*H 7·3							
No substance . . .	*nil*	1·16	0·29	0·52	1·97	...	...
Calcium phosphate (monobasic)	5·63	6·40	0·56	0·50	7·46	5·49	98
Calcium phosphate (dibasic) .	4·61	5·44	0·56	0·50	6·5	4·53	98
Calcium phosphate (tribasic) .	4·58	5·25	0·64	0·63	6·52	4·55	99
Apatite	3·80	2·69	0·69	2·40	5·78	3·81	100
Iron phosphate (normal) .	4·77	1·58	4·00	1·00	6·58	4·61	97
Aluminium phosphate . .	5·82	3·60	0·90	1·44	5·94	3·97	68
Soil—Karimganj, *p*H 4·5							
No substance . . .	*nil*	0·01	0·18	0·08	0·27	...	...
Calcium phosphate (monobasic)	5·63	5·37	0·72	0·18	6·27	6·00	100
Calcium phosphate (dibasic) .	4·61	4·54	0·64	0·16	5·34	5·07	100
Calcium phosphate (tribasic) .	4·58	4·00	0·64	0·17	4·81	4·54	99
Apatite	3·80	2·06	0·56	1·50	4·12	3·85	100
Iron phosphate (normal) .	4·77	0·34	3·36	0·72	4·42	4·15	87
Aluminium phosphate . .	5·82	1·86	2·40	0·40	4·66	4·39	75

APPORTIONMENT OF THE ADDED PHOSPHORUS IN VARIOUS FRACTIONS

Percentage recovery of the added phosphorus in the different fractions is shown in Table III from which it will be seen that about 93 per cent of added mono-, di- and tricalcium phosphates have been recovered along with the acetic acid soluble fraction of the soil phosphorus. The major part of the apatite phosphorus has distributed itself in the strong acid soluble fraction. If, as pointed out before, the high acetic acid solubility of apatite phosphorus is ascribed to the presence of tricalcium phosphate and allowance made for it then the recovery of the apatite phosphorus in sulphuric acid comes to about 83 per cent. Ferric phosphate, on the other hand, has been recovered mostly with the alkali soluble fraction of the soil phosphorus. As before, aluminium phosphate does not give agreeable results. The above observation apply equally well to both the soils. The percentage recovery of the various subs-

tances in the fractionation is nearly the same as the percentage solubility in the solvents used.

TABLE III

Apportionment of the added P_2O_5 in the various fractions

Substance	......	P_2O_5 added	P_2O_5 recovered by acetic acid soln.	P_2O_5 recovered by NaOH soln.	P_2O_5 recovered by H_2SO_4 soln.
			Jessore soil.		
Monocalcium phosphate	Mg. recovered	5·63	5·24	0·27	...
	Per cent recovered	...	93	5	...
Dicalcium phosphate	Mg. recovered	4·61	4·28	0·27	...
	Per cent recovered	...	93	6	...
Tricalcium phosphate	Mg. recovered	4·58	4·09	0·35	0·11
	Per cent recovered	...	89	8	2
Apatite	Mg. recovered	3·80	1·53	0·40	1·88
	Per cent recovered	...	40	11	49
Ferric phosphate	Mg. recovered	4·77	0·42	3·71	0·48
	Per cent recovered	...	9	78	10
Aluminium phosphate	Mg. recovered	5·82	2·44	0·61	0·92
	Per cent recovered	...	42	10	16
			Karimganj soil		
Monocalcium phosphate	Mg. recovered	5·63	5·36	0·54	0·10
	Per cent recovered	...	95	10	2
Dicalcium phosphate	Mg. recovered	4·61	4·53	0·46	0·10
	Per cent recovered	...	98	10	2
Tricalcium phosphate	Mg. recovered	4·58	3·99	0·46	0·09
	Per cent recovered	...	87	10	2
Apatite	Mg. recovered	3·80	2·05	0·38	1·42
	Per cent recovered	...	54	10	37
Ferric phosphate	Mg. recovered	4·77	0·33	3·18	0·64
	Per cent recovered	...	7	67	13
Aluminium phosphate	Mg. recovered	5·82	1·85	2·22	0·32
	Per cent recovered	...	32	38	6

The evidence adduced above, though not free from minor irregularities, would, in general, lend support to the principle of the fractionation adopted. That is, without committing any serious error, the acetic acid soluble fraction can be taken to represent mono-, di- and non-apatite tricalcium phosphate of the soil, the alkali soluble inorganic fraction to represent iron phosphate and a part of aluminium phosphate while the sulphuric acid soluble fraction would represent phosphorus of apatite nature. The phosphorus that would be left in the soil after these combined acid and alkali extractions cannot certainly include the above-mentioned classes in any appreciable amount.

Summary

With a view to deducing the chemical nature of the phosphorus fractions extracted from soil by $N/2$ acetic acid, $N/4$ sodium hydroxide and $2N$ sulphuric acid, solubilities of phosphorus compounds in the above solvents have been studied.

The solubility study shows that (*a*) in acetic acid calcium phosphates are highly soluble, (*b*) in sodium hydroxide the phosphates of iron and aluminium are highly soluble whereas tricalcium phosphate and apatite are highly insoluble, and (*c*) in sulphuric acid all the compounds are highly soluble.

Fractionation of a mixture of soil and various phosphorus compounds shows that most of the mono-, di- and tricalcium phosphates are recovered with the acetic acid soluble fraction and that ferric phosphate is mostly recovered with the alkali soluble fraction.

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STEM-ROT DISEASE OF JUTE

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(With Plate V)

No other single disease of jute (*Corchorus capsularis* and *Corchorus olitorius*) causes more damage, both to outturn and quality of fibre, than the stem-rot due to *Macrophomina Phaseoli* (Maubl.) Ashby [=*Rhizoctonia bataticola* (Taub.) Butler]. Shaw [1912] considered it to be a destructive disease of seedling jute and was of opinion that it was sporadic and occurred in an epidemic form only under certain conditions. Since then it has been found to be of widespread occurrence in Bengal and is reported to occur in Assam, Bihar and Orissa.

The fungus can attack the jute plant both in the seedling and the adult stage, leading to the formation of gaps in the field and reduction in yield. The jute crop is as a rule thickly planted so as to discourage branching and yields in consequence a superior fibre. When the disease is mild and the deaths are few in the crop, there is not much cause for anxiety ; but if the death rate is severe, large gaps may occur and the plants develop stems of uneven thickness which not only take a longer time to ret but produce a coarser fibre. With wider spacings, the plants are induced to branch, rendering them useless for fibre production.

In the adult stage the damage done is of a more serious nature. In addition to loss by deaths in plants that have not succumbed to the disease the stem usually splits and shreds. Such stems take 10 to 15 days more to ret and the fibre itself instead of being glossy, fine and white in appearance (Plate V, fig. 3) is coarse, brownish, weak and lacking in lustre, (Plate V, fig. 2) often with persistence of periderm (Plate V, fig. 4). The fibre from dead stems is uniformly dull, coarse and brittle, studded with the sclerotia of the fungus (Plate V, fig. 1).

Symptoms

Seedlings

On the seedlings, the earliest symptoms manifest themselves either on the hypocotyl in the form of lesions near the collar and the node or on the cotyledonary leaves. They are in thin streaks and blackish-brown to black [Ridgway, 1912]. Under wet conditions the younger seedlings damp off but when conditions are dry and the seedlings have reached a three leaf-stage, they develop blight resulting in the shedding of the leaves and the death of the plants. Blight also occurs when the tender roots get infected. However, in many of the damped off and blighted plants the aerial parts are the first to be affected, the roots being subsequently invaded. On the cotyledonary leaves, the necrotic lesions are orange-citrine and roundish. As rotting of the leaves

and the hypocotyl proceeds, pycnidia are formed in abundance. Sclerotia are, however, formed in all the parts of seedlings.

Growing plants

Leaves. Buffy citrine necrotic lesions occur mainly along the apex and the margins of the leaves ultimately covering the entire leaf including the mid rib and the petiole. A majority of such leaves are shed. Sclerotia have never been observed on the affected leaves but numerous pycnidia cover the entire lamina and the petiole (Plate V, fig. 12). The pycnidial ostiole is generally on the upper surface of the leaf.

Stem. The primary lesions on the stem usually occur at the nodes as small, blackish-brown depressions, which later increase in size in both the directions (Plate V, fig. 6). The streaks vary in size from half an inch to nine inches (Plate V, fig. 7). Several lesions may coalesce and gradually girdle the stem. In such advanced cases, the plants wilt leaving bare dead stalks in the field with abundant pycnidia all over (Plate V, figs. 8 and 11).

Where the streaks run along the length of the stem without girdling it, the cortex gets shredded exposing the fibrous tissue. Adventitious roots may develop at the two ends of the streaks (Plate V, fig. 9) and such plants continue to grow but they break easily when strong wind blows. The plants always remain dwarfed and bushy.

In some vigorously growing plants the lesions may become localized due to cork formation. Such cankers are half to one inch long and dull greenish black in colour. A furrow may form if several such cankers coalesce (Plate V, fig. 10).

A microscopic examination of the infected stems shows the presence of the fungus in all the soft tissues, the epidermis and the cortex being the most affected. Where the infection is widespread the fungus spreads inwards invading the phloem parenchyma and the wide rays between the phloem wedges. It is also found in the central woody portion, the hyphae penetrating even the wood fibres. Pycnidia are usually embedded in the epidermis of the stem and sclerotia are found in the ray-cells and the softer tissues of the phloem and the xylem. In cankers, pycnidia and sclerotia occur sporadically.

Roots

In plants whose aerial parts are attacked, the roots very often are healthy. It is only after all the parts of such plants die, the infection extends to the roots. Sometimes, however, direct infection of roots occurs in which case the plants wilt. Such plants can easily be uprooted and their roots are found to have disintegrated. Attacked roots are invariably full of black sclerotia of the fungus.

Capsules

Discolourations on the capsules are found at all stages of growth. Infected capsules are liable to drop off or split; in the latter case the seeds invariably get infected. In some of the unsplit diseased capsules the seeds also may be diseased. Infected seeds are saval brown, without any lustre and light in weight. Sclerotia are found within the capsule and on seeds. Pycnidia occur on the outer surface of the capsule and sporadically on the seeds. Mycelia and sclerotia of the fungus have been observed under the seed-coat and sometimes in the cotyledons.

The fungus

The morphological characters of the fungus have been well established by Sawada [1916] and Shaw [1924]. A similar fungus was isolated at Dacca Farm from all the affected parts. Monospore isolations from pycnidia found on leaves, stem and capsules and isolations of the sclerotia yielded the same fungus.

In order to make the sclerotial measurements comparable with those given by Haigh [1930], the fungus was cultured on maize meal agar medium prepared according to his formula. He reports that the sclerotia of C strains 'attain their maximum size in four to six weeks'. Consequently the cultures were allowed to grow for six weeks at room temperature which varied from 24° to 27°C. Two hundred sclerotia were measured and their diameters varied from 41 to 86 μ, the mean being 60 ± 0.8 μ. The sclerotia of the stem-rot fungus lie in the C group of Haigh.

Pycnidia from leaves and stems were separately collected and incubated in water at 32°C. till the spores were discharged. One hundred pycnospores were measured soon after their discharge. Pycnospores from leaves were comparatively bigger than those from the stems. The pycnospore measurements furnished in Table I compare well with those recorded by Ashby [1927] for *Macrophomina Phaseoli*.

TABLE I

Measurements of pycnospores

Workers	Source	Length in microns		Width in microns	
		Range	Mean	Range	Mean
Shaw [1924] . .	Jute stem . .	16—27	..	6—8	..
		17—29	..	6—8	..
		16—24	..	7—8	..
		20—27	..	7—9	..
		16—27	..	7—11	..
		16—24	..	8—11	..
Ashby [1927] . .	Jute leaves .	16—28	..	6—8	..
	Bean stem . .	17—30	23·6	6—9	..
	Sesamum stem .	18—29	..	7—9	..
Uppal *et al.* [1937] .	Sorghum seedlings	10—24	..	6—10	..
Authors	Jute leaves .	15·6—27·3	21·3	5·8—9·7	8·1
	Jute stems . .	15·6—27·3	19·9	7·0—9·8	7·9
	Cowpea leaves .	15·6—24·2	19·0	6·8—7·8	7·7

Inoculation experiments

Shaw [1912] succeeded in infecting both the wounded and unwounded stems. Briton-Jones [1928] records successful infection on wounded stems, but it is not clear whether he obtained infection on unwounded stems also. It is found that infection readily occurs on mature stem when the surface of the stem is scratched and inoculated. Unwounded stems can also be successfully infected by maintaining humidity in the region where the inoculum is placed. In such cases the lesions remain localized. Where unwounded collar region of 15 days old plants is inoculated under high humidity, the discolouration is noticeable after 24 hours. The above ground parts of such plants are first to succumb and later the infection penetrates the roots. The cultures from live diseased plants and those from previous season's dead stubbles are equally virulent.

Briton-Jones [1928] could induce root infection of jute seedlings in inoculated gravel cultures under humid conditions. He was not able, however, to infect adult jute plants by soil inoculation. West [1931] grew jute plants to maturity in inoculated sand cultures, but the disease did not appear. As the disease is transmitted through the seed, it became necessary to sow individual seeds in sterilized soil in pots and to transplant only healthy young plants to inoculated soil. Forty plants 20 days old, when transplanted to inoculated soil, showed symptoms within 15—20 days, and succumbed to the disease, the percentage of mortality being 60. Roots of 20 days old healthy plants washed and dipped in a suspension of the culture when transplanted, produced symptoms after two days and subsequently died, the mortality being 85 per cent in a population of 40 . Twenty controls in each of the two experiments remained healthy. The soil, sterilized at 30 lb. pressure for one hour, was inoculated with 10 days old culture grown in Richard's medium. When five adult plants 75—90 days old were transplanted after washing their roots free of soil and dipping them in a suspension of the culture, the infection did not occur. All these inoculation experiments were carried out on plants grown in pots but the regulation of soil temperature or soil moisture in them was not possible. The failure of the fungus to infect adult plants may be due either to resistance offered by older roots or to the absence of proper conditions for favourable infection.

With the aid of an atomizer the pycnospores were sprayed over the leaves of one month old plants and these were kept under bell-jars for 36 hours. After a fortnight, lesions were observed on the different portions of the lamina followed by pycnidia. Pycnospores from these leaves yielded the sclerotial fungus. The original fungus was also recovered from the inoculation experiments.

No infection could be induced by spraying sclerotial suspension on leaves.

Development of disease in the field

Little was known as to the exact nature of the development of this disease in the field. The observations made in the previous two cropping seasons brought out some new aspects. With a view to gain more knowledge about these, the variety D 154 (*C. capsularis*) was grown in a field where heavy stem-rot was observed in the preceding years. Soon after germination, 150 plants

were marked out. For each plant under observation an index card was maintained and records of the weekly progress of the disease were kept till the maturity of the crop. From a study of these cards it is possible to trace the course of the disease from stage to stage. Weekly figures showing the number of plants in which a particular symptom was first observed are presented in Table II.

Table II

Frequency of plants showing a particular symptom for the first time

(Date of sowing—30 April 41 ; flowering commenced in 17th week ; harvest stage for fibre in the 21st week ; harvest of the seed crop 25th week onwards)

Weeks	Symptoms							
	Lesion on seedling	Lesion on leaf	Stem-rot	Stem shredding	Stem canker	Girdling of stem by lesion	Deaths	Lesion on capsule
1 . .	3	..	..	..	..	..	..	..
2 . .	21	..	..	..	..	..	..	..
3 . .	4	13	4	1	..	..	8*	..
4 . .	..	27	26	1	..	7	2*	..
5 . .	..	16	24	2	..	6	12	..
6 . .	..	27	15	11	..	7	11	..
7 . .	..	10	16	8	1	2	2	..
8 . .	..	7	4	11	1	..	1	..
9 . .	..	..	2	5	4	1	2	..
10 . .	..	1	2	2	3	..	1	..
11 . .	..	..	1	1	..	..	..	..
12 . .	..	..	2	3	3	1	1	..
13 . .	..	..	1	1	3	1	..	..
14 . .	..	..	1	..	2	1	1	..
15 . .	..	..	1	1	..	..	2	..
16 . .	..	1	2	..	1	..	2	..
17 . .	..	..	1	..	..	2	..	..
18 . .	..	..	..	..	..	1	3	..
19 . .	..	1	5	1	..	5	1	..
20 . .	..	..	..	2	1	4	6	..
21 . .	..	..	1	2	1	2	3	..
22 . .	..	2	5	..	1	4	3	..
23 . .	..	4	6	1	..	6	5	..
24 . .	..	..	..	2	..	4	7	3
25 . .	..	1	1	..	..	6	9	11
Total .	28	110	120	55	21	60	82	14
Percentage	18·6	73·3	80·0	36·6	14·0	40·0	54·6	9·3

* Damping off

The figures presented are from one year's data only and it is not the intention to use them for showing the extent of the disease which is known to vary from year to year. The primary aim is to confirm the previous two seasons' observations on the sequence of symptoms and the nature of epidemic. The conclusions on these two aspects are, therefore, based on three years' observations.

Out of the 150 plants kept under observation only 10 plants did not record any symptoms ; the remaining 140 plants showed one or more symptoms of stem-rot at some stage or other of their growth. The leaf and stem infections occurred a fortnight after the expression of seedling symptoms. The leaf infection generally leads to the infection of the stem at the nodes (Plate V, fig. 5).

In all, there were 82 deaths made up as follows :—

(*a*) Death attributable to *M. Phaseoli*—	
(*i*) due to damping-off	10
(*ii*) due to ringing	58
(*iii*) after stem-rot	10
Sudden deaths where M. *Phaseoli* was the probable cause—	
(*i*) after leaf infection	1
(*ii*) without any symptom	1
(*b*) Death due to other causes—	
(*i*) Whiteant attack after seedling and leaf infection	1
(*ii*) *Sclerotium rolfsii* after stem-rot	1
Total	82

It is seen that the majority of deaths are largely due to the rot encircling the stem. The interval between the appearance of the stem-rot and the death of the plant ranges between one and twenty weeks. Where the top of the plant is attacked the death is quicker. Over 55 per cent of mortality occurred within two weeks of the commencement of the stem-rot. Attacked plants survive commonly by means of callus formation.

Regarding the extent of infection in relation to the stage of the crop, it is clear from Table III that more than 40 per cent of the plants caught the infection within the first month of their growth. By the eighth week after sowing, the cumulative infection had reached 84 per cent and the mortality which commenced in the third week had also reached a high level. The most critical period for the crop appears to be the first eight weeks of its growth for it is during this period that the disease is serious.

TABLE III

Percentage of infection and mortality

(Date of sowing—30 April 1941 ; flowering commenced in 17th week ; harvest stage for fibre in the 21st week ; harvest of the seed crop 25th week onwards)

Weeks	Symptoms				
	Healthy plants	Fresh infections on the healthy survivals	Cumulative infection	Deaths on the survivals	Cumulative deaths
1	98·0	2·0	2·0	..	..
2	84·0	14·3	16·0	..	..
3	73·4	12·7	26·6	5·3	5·3
4	53·4	27·2	46·6	1·4	6·6
5	43·4	20·0	56·6	8·5	14·6
6	27·4	35·9	72·6	8·6	22·0
7	21·4	21·9	78·6	1·7	23·3
8	16·0	25·0	84·0	0·9	24·0
9	15·4	4·2	84·6	1·6	25·3
10	14·7	4·3	85·3	0·9	26·0
11	14·7	..	85·3	..	26·0
12	14·7	..	85·3	0·9	26·6
13	14·7	..	85·3	..	26·6
14	14·7	..	85·3	0·9	27·3
15	14·7	..	85·3	1·8	28·6
16	14·0	4·5	86·0	1·8	30·0
17	14·0	..	86·0	..	30·0
18	14·0	..	86·0	2·8	32·0
19	13·4	4·8	86·6	0·9	32·6
20	13·4	..	86·6	5·9	36·6
21	13·4	..	86·6	3·1	38·6
22	11·4	15·0	88·6	3·2	40·6
23	8·0	29·4	92·0	5·6	44·0
24	7·4	8·3	92·6	8·3	48·6
25	6·8	9·1	93·2	11·7	54·6

It will be noted (Table III) that when the seed crop was ready for harvest, only 6·8 per cent of the plants remained completely free from the disease while 54·6 per cent had died. As the fibre crop is harvested a month earlier the corresponding figures for that stage are of interest. At that stage the percentages of healthy, infected and dead plants were 13·4, 48·0 and 38·6 respectively. Thus, after the fibre harvest stage the percentage of infection as well as mortality rise again. The most favourable period for the disease is when the plant is below two months or over four and a half months old. From the foregoing it appears that the destructiveness of the disease towards the harvest stage can be got over by earlier harvest as far as the fibre crop is concerned. The seed crop will, however, suffer considerably at the late stage.

Primary infection

The fungus is known to survive in soil and cause seedling infection and root-rot on a number of hosts. In jute fields the fungus perpetuates on stubbles in its sclerotial form. Where rotations are practised, other crops like linseed, sesamum or cowpea may form the alternate host. It is also found to survive on *Cyperus distans*—a common weed in Bengal.

Field observations indicate that excepting under high temperatures, the primary root infection is sporadic.

The fungus harbours on the seed, under the seed coat and within the cotyledons. In some samples as much as 30 per cent of the seeds were found to be infected. Most of the seedling symptoms described occur when contaminated seeds are sown under laboratory conditions. The relative importance of the seed-borne infection as against the soil-borne infection has not as yet been properly assessed. The work of Andrus [1938] with the bean disease caused by the fungus has shown that 'consistently more seedling infection is obtained when the seed is infected before planting than when infection is depended upon to occur from inoculum in the soil'. In view of this and also in view of the importance of the cotyledons in primary infection it seems that the contaminated seed is a more important source of primary infection.

Secondary infection

Pycnidia appear on the cotyledonary leaves and the hypocotyl within a fortnight after sowing or a week after the expression of the primary symptoms. Leaf lesions are noticed immediately in the vicinity of the originally infected plants. The evidence on hand indicates that the pycnospores released from diseased and infected seedlings cause this secondary infection. Abundant leaf infection has been noticed in the fields during and after heavy rains. Under prolonged, warm and humid conditions the leaf infection leads to severe outbreaks of stem-rot. From Table II it will be seen that only 18·6 per cent of plants got primary infection whereas at the seed harvest stage 93·2 per cent of plants were diseased. Thus 74·6 per cent of the total infection was apparently secondary.

When the weather during the first seven weeks of the crop is comparatively dry, the incidence of the disease at Dacca is less. Jute sown on low and *char* lands has been seen to suffer less than that grown on medium or high lands. The crop is sown very early (February—March) in *char* and low land areas and during the first two months of its growth the weather is mostly dry and the

conditions therefore are not as favourable for the spread of the disease as is the case with high land crops which are sown rather late in April or early in May.

Summary

The effect of stem-rot on the quality and outturn of fibre and the symptoms as they appear on various parts of the plant have been described.

The cultures of the fungus isolated from different parts of the diseased plants agree with Haigh's C strain of *Rhizoctonia bataticola*; and the pycnospore measurements agree with those recorded by Ashby for *Macrophomina Phaseoli*.

The fungus is very virulent during the pycnidial stage and forms an important source of secondary infection. Pycnospores readily infect the leaves and the leaf infection spreads to the node through the petiole. The rot of the stem leads to either shredding, canker or wilting.

The primary root-rot usually occurs sporadically, late in the season, and also appears early in the season when high temperatures prevail.

The critical period for the crop and the most favourable period for the disease is before eight weeks or after four and a half months. Late infection is responsible for the contamination of seed.

It is suggested that infected seed is a more important source of primary infection than infection through the soil. The extent of stem-rot epidemic can be gauged from the primary infection, as, usually the secondary infection is four times the primary infection.

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Stem-rot disease of jute due to *Macrophomina Phaseoli*

Sugarcane Research Scheme for Deccan, Padegaon

Treatment	Gypsum alone	Gypsum + F. Y. M.	F. Y. M. alone	Sulphur + F. Y. M.	Control irrigated
Yield of seed cotton in gm.	Nil	Nil	1·072	6·240	Nil
	Partially	Partially	Partially	Reclaimed	Not reclaimed

SOILS OF THE DECCAN CANALS

IV. THE ALKALI SOILS, THEIR NATURE AND MANAGEMENT

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(With Plate VI)

Introduction

Due to extensive occurrence of alkali soils in India and their proverbial infertility a study of these soils presents a very important problem both to the soil scientists and the agriculturists, and a co-ordinated attack on the subject is of vital importance in order to bring back millions of acres of such unproductive lands under proper cultivation. Seriousness of the situation has been only brought into prominence in most cases after the introduction of irrigation water to the arid regions as in the cases of the United Provinces, the Punjab, Sind and Bombay-Deccan. The so-called alkali soils of the United Provinces known as *usar* or *reh* were first investigated by the 'Reh Commission' in 1876, which was appointed to discover the cause of deterioration of lands which had been previously fertile. Leather [1897] in two exhaustive publications has dealt with all the salient points of evidence tendered before the Committee by Medlicott of the Geological Survey of India and others, adding the results of his own investigations on the *usar* lands not only of the United Provinces but also of the Punjab, Gujarat and the Bombay-Deccan. He has included all these saline and alkaline soils under the general term '*usar*'. All the evidence at that time pointed out that the general aridity of the land was the chief cause of formation of these soils. The scanty rainfall is not enough to wash out completely the salts naturally formed in the soil by weathering action. Both Leather (in the same publications) and Wadia [1936] have stressed the fact that under the north-Indian conditions an appreciable addition to the natural salts in the soils may be made by rivers, *nallas* and canals carrying salts in solution. Besides direct addition by surface washings, the raising of subsoil water is a serious consequence of irrigation. A fourth likely cause of formation of these soils, viz. the possible existence of a salt bed below the soil has been disproved by examination of actual bores taken at several places described by Leather.

Henderson [1920] has suggested some practical methods of salt land reclamation for north-west India. He was of opinion that washing of the salts

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into the subsoil was a very effective method of reclaiming such soils. After washing, the physical condition of the soil was improved by suitable cropping.

In the Punjab, Nasir [1923] in his researches on the barren soils of the Lower Bari Doab Colony has shown that though the alkali soils do not much differ in their mechanical analysis from the surrounding normal soil, the compaction, the shrinkage and the defloculation of soil particles are due to the presence of harmful alkali salts. The lands are consequently rendered infertile and deficient in bacterial activity due to these alkali salts. The most suitable method to reclaim such soils, in his opinion, was to open artificial drains and to use gypsum with subsequent flooding to remove salts. Dalip Singh and Nijhawan [1932] have studied the physico-chemical changes accompanying the process of reclamation in alkali soils of the Punjab. They have presented data on the mechanical and chemical analysis of some of these soils and have ascribed the *kallar* trouble mainly to a deficiency in the exchangeable calcium. They have reclaimed these *kallar* soils by the application of gypsum and calcium chloride followed by farmyard manure. Recently, McKenzie Taylor and Mehta [1941] have stated that the soil deterioration in the Punjab is chiefly due to the presence of salts in the soil crust and to the formation of a zone of accumulation of salts with the introduction of irrigation. In studying the effects of salt distribution due to irrigation and growth of cotton and rice, they found that while cotton caused a re-distribution of salts originally present in the soil crust and a formation of zone of accumulation of salts, rice showed a complete leaching out of salts from the profile. From these observations they concluded that deterioration of lands in the Punjab containing salts can be prevented by growing rice.

The *usar* soils of the United Provinces have been successfully reclaimed near Cawnpore and Allahabad by the application of molasses. Dhar [1936] has stressed the fact that molasses, which contain about 60 to 70 per cent of carbohydrates and are distinctly acidic in reaction, can readily reclaim the alkali soils.

Tamhane [1920] has investigated the conditions of salt formation and accumulation in Sind soils. There, the appearance of *kallar* has been traced as not due to waterlogging, but to the downward and upward movement of irrigation water, which leaves the dissolved salts behind as the water evaporates. Such being the case, where there is no layer of sand as a safety layer, leaving the land fallow and absolutely out of cultivation favours the formation of *kallar*.

In the Bombay-Deccan, Mann and Tamhane [1910] in their investigations on the salt lands of the Nira valley have shown that the development of the salt lands in the Nira Canal area was due to the existence of the canal. The drainage condition of the soil being inferior, the subsoil water rose up to the surface causing the land to be waterlogged and salt-affected. They found that the lands can be prevented from being waterlogged and salt-affected by deepening the *nallas* and opening of feeder drains. Inglis [1927], and Inglis and Gokhale [1928] have described reclamation of salt-affected and waterlogged areas in the Deccan. Several land drainage schemes have been carried out in such areas and they have proved effective in most cases in improving the damaged lands by lowering the subsoil water level. Talati [1941] has

recently discussed the formation of waterlogged and salt-affected lands in the Deccan and has attributed causes of damage to the excessive amount of irrigation water applied by the cultivators and to the presence of salts in the soil. He has classified these damaged lands according to the presence of different amounts of salts in the soils and their pH values.

Although considerable work has been done in various places in India on the reclamation of the alkali soils, the knowledge regarding their nature is still very imperfect. This is mainly due to the lack of available data on the morphology of these soils and want of a clear understanding of the pedogenic processes leading to their formation. Hence it is difficult to forecast the probable behaviour of these soils under different intensities of irrigation and cropping. In the present paper, an attempt has been made to arrive at a rational system of management of these soils based on a thorough study of their morphology and chemistry, coupled with field experimentation to follow the dynamics of soil changes under different systems of irrigation, manuring, cropping and fallowing. Reclamation of badly alkaline soils by means of artificial methods has also been dealt with.

Experimental technique

Most of the field and laboratory methods given in a previous publication [Basu and Sirur, 1938] have been followed in connection with the investigations described in this paper. Only the additional methods employed are briefly indicated below :

Water extract of the soil. Soil shaken with water (soil : water ratio 1 : 5) for one hour in an end-over-end shaker and filtered through Pasteur Chamberland filter using Houston's pump.

(*a*) Sodium carbonate—Aliquot titrated with standard $KHSO_4$ solution using phenolphthalein as indicator [Harris, 1920].

(*b*) Calcium—By volumetric method of titration with potassium permanganate [Steenkamp, 1934].

(*c*) Sodium—Colorimetrically using zinc uranyl acetate method [Steenkamp, 1934].

Soil reaction. By the Biilman's quinhydrone method using a soil : water ratio of 1 : 2·5 [Wright, 1934]. Beckman's glass electrode pH meter has recently been employed to check these results. Agreements were very good up to a pH value of 9·0.

Dispersion coefficient. The percentage of clay in the soil was determined by the dispersion in pure water (A) and also by International method (B) and the dispersion coefficient worked out as A/B × 100.

II. Nature of alkali soils

On the Deccan canals a considerable area is covered by a peculiar type of soil which is characterized by impermeability, extreme hardness and occasional presence of undesirable salts on the surface, all of which affect adversely the plant growth. Locally known as '*chopan*', these soils are so far regarded as unsuitable for perennial irrigation and cane-growing. They occur generally in patches from a few acres to a few square miles in extent amidst well-drained

fertile soils of the tract. A large number of alkali soil profiles have been examined on the six major canals of the Deccan and some of the notable features of these soils are indicated below :

Soil depth and subsoil water-table. These soils are usually deep, the depth of the soil over *murum* (or decomposed rock) being sometime over 20 ft. but in certain exceptional cases soils having depths of 3 ft. to 4 ft. have also been found to possess similar characteristics. The subsoil water-table is generally struck between 7 and 12 ft. below the surface. Under waterlogged conditions, however, water-table reaches very near the surface, specially during the monsoon.

Soluble salts and p*H*. A zone of accumulation of soluble salts is a common characteristic of all these soils, the accumulation usually taking place in lower soil layers, i.e. in depths from 30 in. to 60 in. depending on the drainage condition of the soil profile. Exceptions are, however, found where the salts are found to accumulate even in surface layer where the soil occurs in a depression with or without an impervious subsoil. This may also happen where the subsoil water-table is near the surface and the water heavily charged with salts. The ratio of sodium/calcium in the accumulation zone has been found to vary from 0·62 to 9·25, and when the accumulation zone occurs in lower horizons ratios higher than 2 usually indicate a certain degree of compaction of the soil horizon. The *p*H value is usually high throughout the profile but the presence of soluble salts lowers the values to a certain extent depending on the sodium saturation of the complex and the nature of soluble salts.

Exchangeable bases. One of the characteristic property of these alkali soils is the high degree of saturation of the surface soil with sodium base, calcium being proportionately low. The sodium saturation varies from 10 to 40 per cent and calcium saturation from 55 to 85 per cent. This high saturation of the surface soil by sodium base is invariably reflected in the hard and compact nature of the soil. Wide variations in the exchangeable potash and magnesium are noted in different soils, but on the whole they are much higher than those present in the normal fertile soils. To what extent these latter bases affect the soil structure is not definitely known and further researches in these directions are in progress. In the present paper, only the proportion of exchangeable Ca and Na will be considered for assessing the extent of deterioration of these soils.

Soil structure. Usually these soils possess two or more horizons fairly well demarcated. The structure of the 'A' horizon varies from small clods to large clods, or laminated to nutty but is invariably hard and compact. Presence of large percentage of salts, however, modifies the structure of this horizon considerably, and dust-like or single-grained structure may also be seen where the percentage of free salts is too high. The 'B' horizon can be both 'loose and friable' as well as 'hard and compact' and the structure variation is great, viz. from single-grained to crumb or shaly to laminated or plate-like structure can be discerned. Hard and compact layer is usually accompanied by high degree of clay dispersion in water whereas loose and friable layer is associated by low dispersion. The alkalinity test (by phenolphthalein) shows that all these soils do not show presence of sodium carbonate and that there is a great deal of fluctuation of this constituent in the soil profile from season to season. Presence of gypsum crystals in the lower soil layers indicates

openness of soil structure, and these soils are usually well drained when brought under perennial irrigation.

Some typical profiles. Some typical alkali soil profiles are described below together with their physico-chemical properties, topography, etc.

(1) *Soil on flat topography with subsoil water-table below 10-15 ft. from the surface : 'B' horizon compact and impervious*

Profile description

Horizons	Depth	
A	0-24 in. . .	Greyish black soil—hard clods breaking into nut-like structure with a tendency for lamination in lower parts ; loam
B_1	24-32 in. . .	Definitely laminated structure—white nodules (small) of lime appearing ; compact
B_2	32-56 in. . .	Soil same as above but with numerous big white concretions of lime ; the structure less pronounced with increasing depth but very compact
C	56-68 in. . .	Practically yellowish white materia which effervesces strongly with dil. HCl (Same material continues to a great depth)

In a previous publication [Basu and Sirur, 1938], it has been stated that all mature deep soils in the Deccan show a zone of accumulation of salts in the profile. The reason for this is the great aridity due to which the products of soil weathering cannot leach out by normal rainfall (which amounts to 18 in. to 25 in.) unless the depth of the soil overlying *murum* or decomposed rock is limited to 2-3 ft. or less. Here the products of soil weathering accumulate gradually with time in the lower layers but in passing down the profile the soluble salts of the leachate get richer and richer in sodium than in calcium, as the bivalent ion calcium having more replacing power than the monovalent sodium ion, enters more in the complex in the upper layers, replacing more of sodium so that actually in the accumulation zone, Na/Ca ratio is usually high. When this high ratio is attained replacement of calcium by sodium starts (this usually takes place when the ratio is greater than 2·0 [Kelley, 1940] which soon brings about the sodiumization of the lower soil layers. This increased

TABLE I

Profile characteristics of alkali soil

Profile No. 1

Horizon 1	Depth in inches 2	Total soluble salts per cent 3	Sodium carbonate per cent 4	*p*H in water 5	Calcium carbonate per cent 6	Clay per cent 7	Dispersion coefficient per cent 8	Exchangeable		
								Calcium m. e. per cent 9	Sodium m. e. per cent 10	Calcium: sodium ratio 11
A . . .	0-12	0·69	0·011	8·91	5·26	50·50	33·67	35·75	5·86	6·10
	12-24	1·14	0·011	8·83	6·13	56·00	36·61	26·00	16·13	1·61
B_1 . . .	24-32	1·48	0·011	8·69	9·05	53·25	36·15	22·50	16·13	1·39
B_2 . . .	32-44	1·48	0·016	8·69	8·18	49·25	36·04	20·50	16·13	1·27
	44-56	1·31	0·021	8·64	6·72	47·50	44·74	14·00	18·75	0·75
C . . .	56-68	1·04	0·021	8·84	8·47	32·75	46·56	11·00	14·93	0·74

Water-soluble sodium/calcium ratio in accumulation zone = 8·03

sodiumization increases the impermeability of the 'B' horizon and the accumulation zone widens and moves upwards thus affecting the surface soil in time. The process is a slow one but is hastened when the profile shows definite eluviation of clay. These soils are characterized by a very hard and impermeable 'B' horizon which is well reflected in the low Ca/Na ratio of the exchange complex, high dispersion figures, presence of sodium carbonate and high *p*H values generally.

(2) *Soil profile occurring in a low-lying situation: Alkalization on the surface soil in spite of a fairly porous substratum: Subsoil water-table below 10 ft.*

Profile description

Horizons	Depth	
A	0-24 in.	Uniform greyish black soil; hard clods breaking with difficulty; black concretions of lime present; clay loam
B_1	24-58 in.	Mottled brown horizon, brown colour increasing with depth; crumb structure
B_2	58-84 in.	Uniform reddish brown material possessing a shaly structure—fairly porous. Presence of crystals of gypsum and white nodules of lime; proportion of lime nodules increasing with depth; silty loam (Very similar material extends up to 12 ft.)

Such a profile normally gets washings from the surrounding catchment area but as the slopes are gentle the soil solution which accumulates on the surface during the rains percolates easily downwards leaving the top soil almost free from high percentage of soluble salts. But as these soil-washings are normally richer in sodium (and also magnesium) through base exchange at higher slopes the 'A' horizon of this soil gets richer in these bases replacing exchangeable calcium in the form of chlorides, nitrates and sulphates, etc. which leach downwards and accumulate in the 'B' horizon where the proportion of Na/Ca is, therefore, usually low. Gypsum crystals also appear as concretions in this horizon. These soil leachings, therefore, act like a reclaiming agent for the lower soil layers and a porous 'B' horizon ultimately develops in time. The exchange Ca/Na ratio of the lower horizons is higher than that observed in the case of profile No. 1. The dispersion figures are also very low indicating definitely a more porous nature of this horizon.

(3) *Soil of medium depth occurring in a depression: 'B' horizon compact and impervious: Salt incrustations visible in patches on the surface*

Profile description

Horizons	Depth	
A	0-19 in.	Black soil—very compact from the beginning with pronounced lamination in the first eight inches; black nodules of lime present; clay loam
B	19-40 in.	Boundary not sharply demarcated but white concretions of lime appear in this horizon; more sticky and compact than above, which increases with depth
	Below 40 in.	*Murum* thoroughly disintegrated almost like sand—with profuse deposits of lime

TABLE II

Profile characteristics of alkali soil

Profile No. 2

Horizon	Depth in inches	Total soluble salts per cent	Sodium carbonate per cent	pH in water	Calcium carbonate per cent	Clay per cent	Dispersion coefficient per cent	Exchangeable		
								Calcium m. e. per cent	Sodium m. e. per cent	Calcium: sodium ratio
1	2	3	4	5	6	7	8	9	10	11
A	0-12	0·31	...	8·76	8·02	59·50	38·23	31·50	5·66	5·57
	12-24	0·93	...	8·66	8·85	60·75	37·04	24·50	11·52	2·13
B_1	24-36	1·90	0·011	8·54	10·37	59·25	3·38	31·50	11·85	2·66
	36-48	1·90	0·011	8·59	10·64	60·00	3·33	27·50	10·08	2·73
	48-58	1·90	0·016	8·58	11·75	64·75	...	26·50	11·52	2·30
B_2	58-72	2·80	0·005	8·33	7·33	64·00	8·59	37·00	8·86	4·18
	72-84	2·40	0·021	8·61	8·57	62·00	...	25·00	8·76	2·85

Water-soluble sodium/calcium ratio in accumulation zone = 0·96

In this particular case there is an accumulation zone in the surface layer which must have been derived from the washings received from the catchment area, the soil solution being richer in sodium than in calcium salts. As the sodiumization has extended up to the 'B' horizon the permeability of this horizon is not good. This will be also evident from the high dispersion figures as also from the high pH values. The beneficial salts of calcium which are usually formed as a result of base exchange in the upper soil horizon must have been partially leached out into the *murum* below (due to shallow depth of overlying soil layer) thus depriving the 'B' horizon of the advantages which accrue otherwise in such cases when the depth of the soil is considerable as in the previous case. Such types of soil may also develop when the lower soil layers are sandy or when the water-table is near, thus helping the removal of calcium salts which are formed as a result of base-exchange reactions in the upper soil layers.

TABLE III

Profile characteristics of alkali soil

Profile No. 3

Horizon	Depth in inches	Total soluble salts per cent	Sodium carbonate per cent	pH in water	Calcium carbonate per cent	Clay per cent	Dispersion coefficient per cent	Exchangeable		
								Calcium m. e. per cent	Sodium m. e. per cent	Calcium: sodium ratio
1	2	3	4	5	6	7	8	9	10	11
A	0-8	2·28	...	8·43	10·95	55·75	40·81	30·00	8·71	3·44
	8-19	0·83	...	8·74	11·82	43·00	66·86	22·00	7·20	3·06
B . . .	19-31	0·42	...	8·97	15·19	57·75	52·88	18·50	8·06	2·29
	31-40	0·42	...	8·84	16·36	57·00	46·49	18·00	7·46	2·41

Water-soluble sodium/calcium ratio in accumulation zone = 6·07

(4) *Soil with surface salt crust formed as a result of nearness of saline subsoil water-table*

Profile description

Horizons	Depth	
A_0	0-2 in.	Surface crust; breaks up into dry sand-like material with greyish black colour; whitish efflorescence of salt present; sandy loam
A_1	2-8 in.	Darker colour than above; slightly laminated to structureless; moist
	8-18 in.	Same as above but loose and friable with a tendency for lamination. Roots of trees visible
B_1	18-27 in.	Definitely compact and laminated with large number of black nodules present. Only a few roots visible here
B_2	27-36 in.	Sandy and gritty material with presence of white and black lime nodules
B_3	36-48 in.	Compacted sandy material full of lime nodules—whitish concretions mixed with soil (Water-table struck at 4 ft.)
C	48-54 in.	Black material (soil) absent; white limy material forming hard cement-like structure containing innumerable black nodules and sandy patches

All these soils are characterized by a surface crust of salts which are richer in sodium than calcium. Saline subsoil water works from below affecting the lower soil horizons more at first, and then travelling upwards when the soil solution gets gradually lower in Na/Ca ratio due to base-exchange reactions. Exchangeable calcium falls very low in such soils specially in lower layers due to continuous reactions of the following types:

$$Ca\,x + 2NaCl \rightarrow Na_2x + CaCl_2 \quad (1)$$

$$Ca\,x + Na_2CO_3 \rightarrow Na_2x + CaCO_3 \quad (2)$$

of which, probably the reaction represented in (2) is more effective. The compaction of the lower horizons is indicated by high dispersion figures as well as low Ca/Na ratios in the exchange complex.

A broad classification of alkali soils on the basis of the compaction of the 'B' horizon

Generally speaking, it may be said that all deep soils which show a zone of accumulation of salts, and also soils of medium depth which contain a salt profile due to topographic conditions are potentially alkaline soils. All these soils possess well-defined structures (probably with the exception of actually waterlogged soils) and can be classed under the world group 'alkali soils with structure' of Glinka [1927] although the morphological features of these soils are somewhat different from those of the Russian 'Solonetz'. According to Sigmond's [1938] system of soil classification, these soils definitely come under the soil order 'sodium soils' as sodium base mainly determines their characteristic structure and field behaviour. The presence of free salts is only a temporary phase in these soils, and a classification based on the nature of these

TABLE IV

Profile characteristics of alkali soil

Profile No. 4

Horizon	Depth in inches	Total soluble salts per cent	Sodium carbonate per cent	pH in water	Calcium carbonate per cent	Clay per cent	Dispersion coefficient per cent	Exchangeable		
								Calcium m. e. per cent	Sodium m. e. per cent	Calcium sodium ratio
1	2	3	4	5	6	7	8	9	10	11
A_0	0-2	3·64	...	8·09	7·15	31·50	11·90	35·00	16·12	2·17
A_1	2-8	3·20	0·016	8·51	7·98	42·75	72·53	11·50	8·76	1·31
	8-18	2·24	0·021	8·64	8·66	50·75	100·00	12·50	10·33	2·21
B_1	18-27	1·18	0·032	8·37	10·73	51·50	100·00	5·50	9·83	0·56
B_2	27-36	0·32	0·053	8·52	12·10	29·25	100·00	24·00	15·50	1·55
B_3	36-48	0·42	0·058	8·56	10·32	41·50	95·18	1·50	17·92	0·08
C	48-54	0·35	0·064	8·62	13·07	21·00	100·00	5·50	10·89	0·51

Water-soluble sodium/calcium ratio in accumulation zone = 3·89

salts without any reference to the structure profile will be of very little practical value. Various pedogenic processes which lead to the alkalization of these soils have been partially discussed in this paper (and will be fully discussed elsewhere), from which it will be seen that all these processes can be broadly classified into two groups for the purposes of assessing their suitability for perennial irrigation : (1) Processes responsible for the formation of a compact ' A ' horizon but which at the same time help in the development of a porous and well-drained ' B ' horizon ; (2) Processes which develop ultimately the compaction of both ' A ' and ' B ' horizons, thus bringing into existence the worst types of alkali soils. These latter soils resemble more closely the ' Solonetz ' group of soils and will be referred to in this paper as belonging to ' C ' family while the former soils having more affinity to ' Steppe ' alkali soils will be called as ' B ' family, the names ' B ' and ' C ' being retained as the first of these members were named in an earlier paper [Basu and Sirur, 1938].

The causes which lead to the formation of these alkali soils can be stated as under : (1) Great aridity of the tract when combined with great soil depth, (2) topographic situation which affects the surface soil due to salt washings from the surrounding catchment area, and (3) nearness of saline subsoil water brought about usually by indiscriminate irrigation. In the formation of alkali soils due to (1) it is not always necessary to have an impermeable subsoil as found essential in the case of Hungarian alkali soils by Sigmond [1927]. Secondly it is not essential to have great soil depths for the formation of alkali soils as it was supposed formerly because the causes (2) and (3) can bring about alkalization even in the case of medium depths of soils.

So far as the reclamation of these sodium soils is concerned they are placed in a very much more advantageous position when compared with the European alkali soils of this group because of the presence of a large reserve of calcium carbonate in the entire profile. For the amelioration of these soils the prerequisite condition to help the reaction of calcium carbonate with the sodium

clay is to create a humid condition, i.e. opposite of what actually has taken place during the formation of these soils. In other words it is necessary to produce an artificial leaching condition to remove the soluble product of reaction out of the soil zone as represented by the following simple equation :

$$CaCO_3 + Na_2 \times \rightleftharpoons Ca \times + Na_2CO_3$$

in order that these soils may be permanently improved. Irrigation, therefore, seems to be the fundamental need for the amelioration of these soils. Of course, it is pre-supposed that the drainage condition of the subsoil will be fairly good in order that the reaction represented in the above equation can proceed in the right-hand direction. Such a case is presented in all soils belonging to the group 'B' where the 'B' horizon is permeable. A series of experiments to study the effects of irrigation, manuring, cropping and fallowing on this group of soil are described in section III while reclamation by artificial methods is discussed in section IV. In the case of 'C' group of soils, great precautions will have to be taken if such soils are to be brought under irrigation. The provision of a drainage system will be an essential feature in these soils, at least in the earlier stages of crop growing. Often times, these latter soils are found to be completely unfit for the growing of irrigated crops when artificial methods recommended in section IV will be found useful.

III. Management of alkali soils

It has already been emphasized that one of the most undesirable properties of these soils from the point of view of their management lies in their possession of an invariably hard and compact surface soil. Due to this property considerable difficulties are encountered by the cultivators in securing a proper tilth, and consequently the germination of seeds and root developments are hindered in earlier stages. Further, due to an impervious nature of these soils a badly puddled condition is usually created on irrigation, and proper nitrification is checked. For these reasons the crops suffer badly whenever proper precautions are not taken in cultivating and irrigating these soils. As the bad nature of these soils is mainly due to high saturation of the clay complex by sodium base, their improvement can only be achieved through the replacement of sodium by calcium following the well-known methods of base exchange. As there is always an abundant supply of calcium carbonate in all these alkali soils the above reaction can take place only through irrigation.

Comprehensive experiments were, therefore, laid out on a typical alkali soil where the 'B' horizon is definitely well-drained. Such an alkali soil was obtainable at the Padegaon Farm, and its description is given in profile No. 2 in the previous section. As besides irrigation, both manuring and cropping are supposed to help favourably the base-exchange reactions by the production of carbon dioxide as a result of improved bacterial activities and root reactions, the following series of experiments were designed in single plots to assess the soil changes after a number of years :

(A) Irrigation and manuring

(B) Cane cropping and fallowing

(C) Rotational cropping

The determinations of only exchangeable calcium, sodium and soil reaction are done to study the nature of soil colloids as affected by different factors of cane growing. Any improvement in soil colloids due to the effects of these factors will be judged by the increase in the calcium/sodium ratio, and in lowering of the soil reaction.

A. *Irrigation and manuring series*

This experiment was started in single plots (size 18·15 ft. × 12 ft. or 1/200 of an acre) in a block with proper bunds, and arrangement for measuring the water by means of a standing wave flume. The treatments on acre basis were as follows :

Water	(1) 70 A″ (2) 95 A″ (3) 120 A″
Manure	(*i*) Nitrogenous—300 lb. N—(4) & (5)
	(4) Sulphate of ammonia
	(5) Farmyard manure
	(6) Green-manure (sunn)
	(*ii*) Phosphatic—600 lb. P_2O_5
	(7) Superphosphate
	(*iii*) Potassic—600 lb. K_2O
	(8) Muriate of potash
	(9) Sulphate of potash
Control	(10) Dry plot

All the treatments from No. (4) to (9) received irrigation of 95 A″ per annum excepting the treatment (6). The changes in the exchangeable calcium, sodium, calcium : sodium ratio and soil reaction will be seen from Table V where the original values and the values after four years of experimentation are recorded. The critical differences for significance have been worked out from previous experience.

It will be observed that in all cases the exchangeable calcium has increased and in some cases the changes are considerable. Even in dry control plot there has been significant increase in exchange calcium, and this may be attributed to the effect of bunding which brings about the leaching down of rain water within the profile in a more efficient way than when there is no bund. Increasing doses of water have effected progressive increases in exchangeable calcium. Addition of manure has helped further the base-exchange reaction only in the cases of sulphate of ammonia, farmyard manure, and superphosphate. The last treatment, however, has not reached the level of significance over the control dose of 95 A″ of water. Reduction in sodium base has taken place in most cases ; but only in the manured plots the changes are appreciable, the greatest reduction being observed in the farmyard manure-treated plot. It will be seen that the reductions in sodium base in all cases are far lower than the corresponding increases in calcium, thus showing that the replacement of other bases by calcium must have also taken place simultaneously. From the changes in the calcium : sodium ratios it will be evident that great improvements in the soil colloids have taken place in most of the manured treatments. Even in the case of irrigation alone, 95 and 120 acre-inches treatments have significantly improved the soils. The first four treatments in order of efficacy are farmyard manure > sulphate of potash > muriate of potash > sulphate of ammonia. As regards soil reaction, both the water treatments 95 A″ and

TABLE V

Effect of irrigation and manuring on the exchangeable calcium, sodium, calcium/sodium ratios and soil reaction

Treatment	Exchangeable calcium m. e. per cent			Exchangeable sodium m. e. per cent			Calcium/sodium ratio			pH in water		
	Original	After 4 years	Difference	Original	After 4 years	Difference	Original	After 4 years	Difference	Original	After 4 years	Difference
Water 70A″	41·00	45·50	4·50	4·58	4·53	—0·05	8·95	10·04	1·09	8·72	8·64	—0·08
Water 95A″	39·50	47·75	8·25	4·53	4·43	— 0·10	8·72	10·78	2·06	8·89	8·60	—0·29
Water 120A″	39·50	49·25	9·75	4·63	4·53	—0·10	8·53	10·87	2·34	8·86	8·62	—0·24
Sulphate of ammonia	39·00	49·00	10·00	4·68	3·66	—1·02	8·34	13·38	5·04	8·80	8·36	—0·45
Farmyard manure	40·00	50·00	10·00	6·10	2·93	—3·17	6·56	17·07	10·31	8·81	8·72	—0·09
Green manure	39·75	44·75	5·00	5·23	3·84	—1·39	7·60	11·66	4·06	8·79	8·74	—0·05
Superphosphate	36·75	46·75	9·00	5·16	4·03	—1·13	7·13	11·35	4·22	8·89	8·72	—0·17
Muriate of potash	38·00	43·75	5·75	5·84	3·58	—2·26	6·51	12·22	5·71	8·80	8·50	—0·30
Sulphate of potash	38·25	46·75	8·50	6·33	3·50	—2·83	6·04	13·36	7·32	8·84	8·80	—0·04
Control dry	39·00	41·00	2·00	6·33	6·20	—0·13	6·16	6·62	0·46	8·89	8·86	—0·03
Critical difference for significance	..	..	1·58	..	..	0·99	..	..	1·50	..	..	..

120 A″ have appreciably lowered the pH values when compared with the dry control while amongst the manure treatments only sulphate of ammonia has given higher drop in pH than the 95 acre-inches of water. Thus, although there has been greater improvement in soils due to manuring, this effect is not reflected in their pH values. The basic nature of these fertilizers partly accounts for this fact while in the case of farmyard manure increase in buffering capacity may be held responsible for such peculiar action.

B. *Cane cropping and fallowing series*

In this experiment 12 plots of dimensions 45·5 ft. × 24 ft., i.e. 1/40 of an acre, were laid out with different systems of cane growing and fallowing as shown below, the crops being continuously grown year after year :

(1) Manjri standard method (cane grown according to standard Manjri system, i.e. 150 lb. N given half as sulphate of ammonia and half as cake)

(2) Continuous plant cane (unmanured)

(3) Continuous plant cane (manured ; basal dose of 40,000 lb. per acre farmyard manure ; top-dressing 150 lb. N per acre as sulphate of ammonia and cake in equal proportions)

(4) Continuous ratoon (unmanured)

(5) Continuous ratoon (manured ; for the first crop same manure as in plant cane and for succeeding ratoon crops, top-dressing with 100 lb. N in equal proportions of sulphate of ammonia and cake)

(6) *Adsali* (unmanured)

(7) *Adsali* (manured ; basal dose of 40,000 lb. farmyard manure per acre, top-dressing 200 lb. N of which 75 lb. N applied as sulphate of ammonia and the rest as cake. The crop allowed to grow for 22 months, allowing only two months for the preparation of land for next cropping)

(8) *Adsali* (Cultivator's method, crop harvested after 18 months and land left fallow till next planting ; manure same as in manured *adsali* crop)

The different systems of fallows were :

(9) Uncultivated and irrigated (Uc. I.)

(10) Uncultivated and un-irrigated (Uc. Ui.)

(11) Cultivated and irrigated (C. I.)

(12) Cultivated and un-irrigated (C. Ui.)

For the sake of abbreviation these fallows will be referred to in the subsequent paragraphs by the letters indicated in brackets. Irrigated fallows were introduced in the above system primarily to leach out the salts and secondly to encourage the natural weed growth in this alkaline soil.

Excepting in the case of Uc. Ui. fallow there have been increases in exchange calcium after four years of experimentation in all cases, although in the case of manured cane, *adsali*—cultivator's method, and C. I. fallow the increases are not appreciable (Table VI). It is curious to note that increases in exchange calcium are more in all the unmanured canes than in manured ones. Among the fallows, Uc. I. fallow shows the highest increase while Uc. Ui. shows actually a lowering (which is, however, not significant). In the case of exchange sodium all cane treatments excepting unmanured plant cane and cultivator's *adsali*, have shown significant reduction. Among the fallows, beneficial effects of irrigation in lowering exchangeable sodium is evident, weeds actually

TABLE VI

Effect of cane growing and fallowing on the exchangeable calcium, sodium, calcium/sodium ratios and soil reaction

Treatment	Exchangeable calcium m. e. per cent			Exchangeable sodium m. e. per cent			Calcium/sodium ratio			pH in water		
	Original	After 4 years	Difference	Original	After 4 years	Difference	Original	After 4 years	Difference	Original	After 4 years	Difference
Cane												
Manjri standard method	38·75	41·15	2·40	9·01	6·08	—2·93	4·30	6·77	2·47	8·34	8·21	—0·13
Unmanured	36·25	42·00	5·75	5·42	3·84	—1·58	6·69	10·94	4·25	8·34	8·22	—0·12
Manured	39·50	41·25	1·75	6·15	3·53	—2·62	6·42	11·70	5·28	8·79	8·31	—0·48
Ratoon												
Unmanured	36·15	39·15	3·00	9·38	6·91	—2·47	3·86	5·67	1·81	8·66	8·44	—0·22
Manured	39·00	41·55	2·55	7·30	5·04	—2·26	5·34	8·25	2·91	8·46	8·32	—0·14
Adsali												
Unmanured	36·85	40·90	4·05	8·32	5·27	—3·05	4·43	7·77	3·34	8·61	8·34	—0·27
Manured	34·85	38·25	3·40	11·07	6·23	—4·84	3·15	6·14	2·99	8·74	8·27	—0·47
Cultivator's method	35·80	36·00	0·20	10·34	8·60	—1·74	3·46	4·19	0·73	8·42	8·19	—0·23
Fallow												
Cultivated and irrigated	37·85	39·05	1·20	8·86	6·16	—2·70	4·27	6·34	2·07	8·46	8·21	—0·25
Uncultivated and irrigated	38·40	41·60	3·20	9·88	6·09	—3·79	3·89	6·83	2·94	8·32	8·21	—0·11
Uncultivated and un-irrigated	39·50	38·25	—1·25	10·93	11·60	0·67	3·61	3·30	—0·31	8·29	8·52	0·23
Cultivated and un-irrigated	39·55	41·75	2·20	8·00	7·76	—0·24	4·94	5·38	0·44	8·37	8·32	—0·05
Critical difference for significance	..	..	2·02	..	..	2·18	..	..	1·38	..	..	..

helping the process still further. Finally, it will be seen that significant increases in the calcium/sodium ratios, thus indicating the improvement in the soils, have taken place in case of all the cane treatments excepting in the *adsali* according to cultivator's method, the descending order of improvement of the first four treatments being manured plant cane > unmanured plant cane > unmanured *adsali* > manured *adsali*. This inefficiency of the cultivator's *adsali* treatment in improving the soil colloid seems to be mainly due to the longer period of summer fallow as practised by the cultivators, which is detrimental in these soils. This aspect is fully discussed later on. In the case of fallows, both the irrigated fallows show significant improvement. Among the cane treatments only manured plot has shown appreciable lowering in *p*H value. The lowering in *p*H in cultivated and irrigated fallow is of the same order as that of irrigated control (i.e. 95 A″) while cultivated and unirrigated fallow is similar to dry control. In spite of greater improvement in soil condition in the uncultivated and irrigated plot the lowering in *p*H is less pronounced. Uncultivated and unirrigated fallow indicates the danger of fallowing these soils in the natural condition.

C. *Rotational crop series*

Several common rotational crops usually grown in this tract were taken in small plots (size 43·35 ft. × 20 ft., i.e. 1/50 of an acre) in a block for two years in succession and soil samples analysed. The result after two years of experiment is given in Table VII. The following crops were grown: (1) *Rabi jowar* (*Andropogon sorghum*), (2) Wheat, (3) Berseem (*Trifolium alexandrinum*), (4) *Shevri* (*Sesbania aegyptiaca*), (5) Cotton, (6) Tobacco, (7) *Dhaincha* (*Sesbania aculeata*) and (8) Rice.

The 'difference' column shows that the exchangeable calcium has increased in all cases excepting in wheat (where there is a slight reduction). Rice, *shevri*, berseem and tobacco have shown significant increases. There have been definite lowerings in exchangeable sodium in all treatments, berseem and *dhaincha* showing the highest figures. From the increases in the calcium/sodium ratios it can be judged that even within two years of crop growing considerable improvement in the soil complex has taken place in all cases, the order of superiority for the first four crops being berseem > rice > *dhaincha* > cotton. It is interesting to note that the four crops mentioned above showed significant improvement even after first year of cropping. In this rotational series the changes in *p*H values are very little excepting in the case of cotton, although the improvement in the soil (as indicated by increase in base ratios) is greatest in the case of berseem.

In order to see whether the loss of exchangeable sodium in the soils due to cropping can be accounted for, by the removal of this base by crops, analysis of these rotational crops was undertaken. This revealed the fact that while the actual uptake by plants varied from 6 to 43 lb. in case of different crops the loss of exchangeable sodium amounted from 422 lb. to 1488 lb. per acre-foot of soil. Thus the plant uptake can account only for an insignificant part of the sodium lost from the soil due to cropping. Root reaction (i.e. production of carbon dioxide by roots), therefore, appears to play an important role in the reclamation of these alkali soils under irrigation, whereby the replaced sodium

TABLE VII

Effect of rotational crops on the exchangeable calcium, sodium, calcium/sodium ratios and soil reaction

Crop	Exchangeable calcium m. e. per cent			Exchangeable sodium m. e. per cent			Calcium/sodium ratio			*p*H in water		
	Original	After 2 years	Difference	Original	After 2 years	Difference	Original	After 2 years	Difference	Original	After 2 years	Difference
Rabi jowar	33·00	34·00	1·00	6·60	5·43	—1·17	5·00	6·26	1·26	9·03	8·98	—0·05
Wheat	32·50	31·00	—1·50	7·60	5·84	—1·76	4·28	5·31	1·03	8·87	8·80	—0·07
Berseem	31·25	33·50	2·25	6·84	4·03	—2·81	4·57	8·31	3·74	8·93	8·89	—0·04
Shevri	29·00	33·00	4·00	6·83	6·05	—0·78	4·25	5·46	1·21	9·01	8·98	—0·03
Cotton	32·25	34·00	i·75	7·07	5·43	—1·64	4·56	6·26	1·70	9·06	8·76	—0·30
Tobacco	31·00	33·00	2·00	6·95	5·76	—1·19	4·46	5·73	1·27	8·98	8·89	—0·09
Dhaincha	31·00	32·00	1·00	7·07	4·98	—2·09	4·38	6·43	2·05	8·81	8·74	—0·07
Rice	30·25	34·25	4·00	5·76	4·63	1·13	5·25	7·40	2·15	8·84	8·77	—0·07
C. D. for significance	..	..	1·94	..	..	0·78	..	..	0·53	..	..	..

ion (as sodium carbonate) is completely leached out. In the case of sugarcane, however, it is found that a considerable amount of sodium is removed by different varieties, and the sodium base removed by the crop may amount to about one-third of the total loss from the soil as a result of cane growing.

Harmful effect of summer fallowing and methods of mitigating it. It has already been shown in a previous experiment that fallowing without irrigation is actually harmful to the soil as it tends to lower the calcium/sodium ratio of the complex. It was thought necessary, therefore, to study the movement of soluble calcium and sodium in the profile to find out the danger period when the alkalization of the surface soil can take place due to differential movements of these bases. Water-soluble calcium and sodium were determined monthly in 6 in. depths of a *chopan* soil profile during the whole year and the results are given in Table VIII. It will be observed that the soluble calcium up to a depth of 24 in. is fairly low (with very little fluctuation during the year) while below this depth the figures are invariably very much higher throughout the year. In the case of sodium also the lower layers (i.e. 24-30 in. and 30-36 in.) contain much more of the base than the upper 24-in. layers but the actual sodium in these upper layers is five to ten times more than calcium. There is a steady rise of sodium, specially in the surface 6 or 12 in. of soil from January to May, after which the sodium content goes on decreasing. A slight drop in May from April may be due to a heavy shower of rain (1·60 in.) which fell in the latter half of April. From June to November (i.e. during the monsoon) a steady low level is maintained. It appears, therefore, that the sodiumization of the surface soil due to the movement of water-soluble salts is likely to be most active during the summer months, i.e. from March to May. Thus summer fallowing in these soils would be a dangerous practice.

In order to study whether growing of lucerne and *shevri* (which can be conveniently grown during summer months) would be effective in checking the rise of sodium salts in the soil profile, soil samples were analysed for two periods during April and May and the results are given in Table IX. It will be clear that in the case of lucerne considerable lowering in soluble sodium takes place over the entire profile while with *shevri* the improvement is only in the first foot of soil during the first period but proves slightly better in the second. With regard to calcium there is a general increase of this constituent over the entire profile. The experiment thus stresses the importance of growing irrigated crops like lucerne and *shevri* on the land during the summer period.

IV. Reclamation by artificial methods

In the previous section it has been shown that considerable improvement in soil can be achieved by simple process of cropping where irrigation and manuring are practised. There are, however, certain extreme types of alkali soils existant on the tract (such as degraded 'C' type soil) where crop growing is often not possible. In such cases it was felt that previous reclamation of soils by artificial methods will be required. For this purpose a new set of experiments was started involving the use of farmyard manure, gypsum, sulphur and molasses. The results of this experiment are described in this section.

TABLE VIII

Movement of water-soluble calcium and sodium in the profile

(mg. per 100 gm. of soil)

Depth in inches	Bases	January	February	March	April	May	June	July	August	September	October	November	December
0-6	CaO	14·00	33·04	33·60	50·40	32·48	32·50	40·90	43·70	39·20	47·60	44·80	57·68
	Na_2O	121·36	143·67	189·39	316·46	255·10	154·32	150·60	162·33	145·34	158·22	148·80	97·64
6-12	CaO	12·88	12·32	13·44	11·20	14·56	19·60	15·10	14·56	14·00	12·88	15·10	20·16
	Na_2O	105·04	100·00	173·61	271·74	156·25	192·30	114·77	119·04	116·82	115·74	93·98	87·41
12-18	CaO	14·56	14·00	21·80	12·05	17·36	17·90	14·00	17·90	14·56	11·76	21·28	22·40
	Na_2O	134·40	116·82	162·33	242·71	126·26	168·61	113·63	130·20	145·36	117·92	100·00	120·19
18-24	CaO	16·86	21·28	11·76	10·90	29·12	57·70	15·70	14·00	17·90	11·76	26·88	26·88
	Na_2O	130·20	148·80	156·25	378·78	245·09	347·22	164·47	109·64	156·25	131·57	107·76	138·88
24-30	CaO	120·96	262·08	300·16	150·90	102·48	206·10	156·80	70·00	103·60	180·88	20·72	106·96
	Na_2O	290·72	312·50	390·60	595·23	265·95	490·19	531·91	352·11	337·83	347·22	189·38	245·09
30-36	CaO	206·08	243·60	303·52	245·00	221·20	259·30	226·80	169·68	202·72	190·40	162·40	264·32
	Na_2O	337·84	403·22	462·96	735·29	297·61	520·83	555·55	438·58	396·82	297·61	260·41	396·82

This experiment was conducted for two years in small plots (14 ft. × 8 ft. or 1/400 of an acre) with provision for flooding with suitable bunds. Shallow drains (about 2 ft. deep) were also maintained for the removal of excess water

TABLE IX

Movement of water-soluble calcium and sodium (mg. per 100 gm. of soil) in the profile under dry (control), lucerne and shevri

—	Depth in inches	April		May	
		Calcium oxide	Sodium oxide	Calcium oxide	Sodium oxide
Dry (control)	0-6	50·40	316·46	32·48	255·10
	6-12	11·20	271·74	14·56	156·25
	12-18	12·05	242·71	17·36	126·26
	18-24	10·90	378·78	29·12	245·09
	24-30	150·90	595·23	102·48	265·95
	30-36	245·00	735·29	221·20	297·61
Lucerne	0-6	17·90	100·80	28·56	162·33
	6-12	19·90	77·16	19·04	92·59
	12-18	8·40	97·65	96·88	164·47
	18-24	226·25	378·78	235·76	219·30
	24-30	246·70	462·96	156·80	160·26
	30-36	219·25	595·23	143·92	215·51
Shevri	0-6	30·80	166·66	24·06	73·52
	6-12	12·30	134·40	14·00	45·62
	12-18	13·15	328·94	15·70	81·17
	18-24	184·50	714·28	203·28	201·61
	24-30	224·00	694·44	316·96	208·33
	30-36	294·00	806·45	259·28	201·61

in-between the plots, the distance between the adjacent plots being 8 ft. A series of nine plots (consisting of 3 plots in 3 rows) was started in the first year. and the following treatments were tried :

(1) Sulphur + farmyard manure
(2) Control (irrigated)
(3) Sulphur alone
(4) Sulphur + farmyard manure + gypsum
(5) Gypsum + farmyard manure
(6) Sulphur + gypsum
(7) Farmyard manure alone
(8) Control (dry)
(9) Gypsum alone

The dose of sulphur was ½ ton per acre, gypsum 1 ton and farmyard manure 5000 lb. per acre. The reclaiming agents were applied to the soil in the month of June every year and were allowed to react during the monsoon. The treated plots were then flooded to the height of 6 in. every day for five days continuously and allowed to drain for the next five days during the closure of the canal. This process was repeated for a period of three months in succession. During this experiment the heights of standing water after 24 hours were recorded in each treatment. Considerable improvements, as judged by the drainage condition of the treated plots, were observed, specially in the cases of treatments No. (1) and (4) in the first year and also in (3) and (6) in the second year. The soil samples were collected at the end of every year and the analytical data after two years of experimentation are only given in Table X.

It will be evident that significant increase in exchange calcium has taken place in all cases except in the dry control where it has shown a slight lowering. The highest increase is recorded in the case of sulphur + farmyard manure + gypsum treatment. Reduction in exchangeable sodium is observed in all cases, the most prominent among them being the treatments (1), (4), (3) and (6), i.e. where sulphur is applied alone or in combination. From the point of view of final improvement, as judged by calcium/sodium ratio, it will be noted that significant increases have taken place in all cases excepting dry control. The first four treatments in descending order of improvement are as follows : Sulphur + farmyard manure > sulphur + gypsum + farmyard manure > sulphur alone > sulphur + gypsum.

In the case of molasses, experiment was started after one year in three adjacent plots and continued for two years as in the previous case. The treatments were :

(10) Molasses 10 tons per acre
(11) Molasses 5 tons per acre
(12) Control (irrigated)

In short it may be said that although molasses have brought about reclamation of these soils, they are definitely inferior when compared with the sulphur treatments, although superior to farmyard manure or gypsum alone.

Considerable lowering in pH values is observed in all the treated plots when compared with the controls. The drops in pH are round about 0·49 to 0·66 in most of the treatments excepting the ' sulphur + gypsum ' treatment where

TABLE X

Effect of reclaiming agents on the exchangeable calcium, sodium, calcium/sodium ratios and soil reaction

Treatment	Exchangeable calcium m. e. per cent			Exchangeable sodium m. e. per cent			Calcium/sodium ratio			pH in water		
	Original	After 2 years	Difference	Original	After 2 years	Difference	Original	After 2 years	Difference	Original	After 2 years	Difference
Sulphur + Farmyard manure	33 ·50	37 ·75	4 ·25	8 ·96	2 ·30	—6 ·66	3 ·74	16 ·41	12 ·67	8 ·94	8 ·28	—0 ·66
Control irrigated	32 ·50	35 ·00	2 ·50	9 ·90	8 ·96	—0 ·94	3 ·29	3 ·91	0 ·62	8 ·73	8 ·72	—0 ·01
Sulphur alone	32 ·50	34 ·75	2 ·25	9 ·48	3 ·93	—5 ·55	3 ·43	8 ·84	5 ·41	9 ·03	8 ·54	—0 ·49
Sulphur + Gypsum + F. Y. M.	32 ·25	39 ·50	7 ·25	9 ·21	2 ·68	—6 ·53	3 ·50	14 ·74	11 ·24	8 ·99	8 ·37	—0 ·62
Gypsum + F. Y. M.	32 ·75	34 ·50	1 ·75	9 ·48	6 ·45	—3 ·03	3 ·46	5 ·35	1 ·89	9 ·03	8 ·46	—0 ·57
Sulphur + Gypsum	32 ·50	36 ·75	4 ·25	10 ·08	4 ·48	—5 ·60	3 ·22	8 ·20	4 ·98	9 ·39	8 ·49	—0 ·90
F. Y. M. alone	31 ·00	33 ·25	2 ·25	10 ·08	6 ·45	—3 ·60	3 ·08	5 ·16	2 ·08	9 ·03	8 ·46	—0 ·57
Control dry	33 ·00	30 ·75	—2 ·25	10 ·08	8 ·71	—1 ·37	3 ·27	3 ·53	0 ·26	9 ·03	8 ·86	—0 ·17
Gypsum alone	31 ·50	34 ·25	2 ·75	10 ·40	7 ·53	—2 ·87	3 ·03	4 ·55	1 ·52	9 ·11	8 ·46	—0 ·65
C. D. for significance	..	..	1 ·06	..	..	0 ·68	..	..	0 ·31	..	..	..
Molasses (10 tons)	30 ·50	34 ·50	4 ·00	10 ·08	5 ·30	—4 ·78	3 ·03	6 ·51	3 ·48	..	..	..
Molasses (5 tons)	28 ·75	39 ·00	10 ·25	9 ·95	7 ·47	—2 ·48	2 ·89	5 ·22	2 ·33	..	..	..
Control irrigated	30 ·50	34 ·50	4 ·00	10 ·40	9 ·82	—0 ·58	2 ·93	3 ·51	0 ·58	..	..	..

the lowering is 0·90. In the control plots the changes in soil reaction are practically very little. There appears to be, however, no clear-cut relation between the extent of reclamation as judged by the increase in the exchange calcium sodium ratio, and the lowering in *p*H. Whatever the initial *p*H values may be, the process of reclamation seems to have brought down the final *p*H values after two years to round about 8·4—8·5 excepting in the best reclaimed soil 'sulphur + farmyard manure', where the *p*H is lowered still further. It is curious to state here that these soils when leached in contact with calcium carbonate attain a *p*H value of nearly 8·2. Thus the lowest limit that can be expected for these soils to attain in any reclamation experiment is 8·2, and the actual lowering in *p*H is virtually governed by the state of original *p*H level in these alkaline soils. The success of a reclamation experiment can, therefore be judged roughly by the final *p*H when it approaches the limiting value of 8·2 in water. The KCl *p*H has shown lowering in values of the same order in all cases including even the control plots. These values are not reported here as they do not show any striking variations between the reclaimed and unreclaimed soils.

Fertility status of the reclaimed soils. In order to study the effect of reclamation on the fertility status of the soils, Neubauer's seedling method [Stewart, 1932] for available phosphate and potash was tried with six soils having calcium/sodium ratios varying from 16·41 in the best reclaimed soil (sulphur + farmyard manure), 5·16--4·55 in the partially reclaimed soils (farmyard manure alone and gypsum alone) to 3·55 in the unreclaimed control (dry). As regards available phosphate the reclaimed soils showed higher values (7·9 mg. per 100 gm. soil) as compared with the control (3·9 mg. per 100 gm. soil) thus indicating more availability of phosphate by reclamation. In case of available potash, however, the two best reclaimed soils showed very high figures (20·1 and 30·2 mg. per 100 gm. soil) but the farmyard manure-treated soil which was only partially reclaimed showed high availability (28·9 mg. per 100 gm. soil) in spite of fairly low value of calcium/sodium ratio (i.e. 5·16). This peculiar behaviour of the soil reclaimed by farmyard manure was noticed in the pot-culture experiment with cotton and also reflected in the quality of *gul* produced from cane grown on this soil, which is discussed later.

Since it is well known that carbon dioxide evolution is an index of microbiological activities in the soil, evolution of carbon dioxide was measured to study the improvement in the soils by reclamation. Respiration studies were carried out for a period of 12 days and the total production of carbon dioxide from different soils compared. The results indicated that the quantity of carbon dioxide evolved was in good agreement with the state of reclamation of the soil, the maximum evolution being given by the best reclaimed soil and the least by the controls (both dry and irrigated), partially reclaimed soils giving intermediate values. The total production in the 12-day period was in the following descending order :

Sulphur + farmyard manure > gypsum > farmyard manure > dry control > irrigated control

Pot-culture work with cotton using the reclaimed soils. The soils obtained from the reclamation experiment were subjected to a pot-culture experiment with cotton (Banilla variety) as a test crop to ascertain to what extent these improvements as judged by the base ratios hold good when the actual soil

fertility is measured in terms of crop yields. The crop was grown in the usual way in five replicates and the results are briefly discussed below :—With the exception of farmyard manure treatment (where the calcium/sodium ratio is 5·16) the opening of the bolls took place only up to calcium/sodium ratio of 8·20. Among the best reclaimed soils, sulphur + gypsum + farmyard manure treatment produced more yield of cotton per boll although sulphur + farmyard manure treatment gave the highest total yield. From the points of view of height and total dry matter also the two reclaimed soils top the list. Photo showing the growth of cotton plant in certain selected treatments is given in Plate VI (facing page 157).

Reclamation and the quality of gul. In the experimental plots, where the reclamation of soil by artificial method was tried for two seasons sugarcane (variety Co 360) was grown in order to finally find out how the quality of *gul* is influenced by the various methods of reclamation. It may be mentioned here that the quality of *gul* is one of the most important consideration with the cultivators, the *gul* obtained from these alkaline soils being usually of an inferior quality. *Gul* blocks were, therefore, carefully prepared, separately from sugarcanes grown in these plots and assessed by the local experts with the following results. *Gul* produced from the farmyard manure-treated plot was best from all points of view, and sulphur-treated plots also (alone and in combination) gave superior quality of *gul*. On the whole, soils with higher calcium/sodium ratio gave better colour and test of *gul* than the control soils, (both irrigated and dry) where the ratios were lower. Thus the beneficial effect of reclamation on the quality of *gul* is clearly manifested.

V. General conclusions and summary

A considerable part of the commandable area of the Deccan canals is occupied by a peculiar type of alkaline soil which is characterized by impermeability, extreme hardness and occasional presence of harmful salts, all of which affect adversely the plant growth. Locally known as *chopan* these soils are so far regarded as unsuitable for perennial irrigation and cane growing. It was, therefore, thought desirable to undertake detailed investigations on the nature of these soils in order to classify them from the point of view of irrigation suitability and devise means for their management. Results of these studies are briefly indicated below :

(1) From an examination of a number of alkali soil profiles situated on different canals it was found that the most common feature of these soils is the high saturation of the surface soil with sodium base which is responsible for the above-mentioned undesirable qualities of these soils.

(2) All these soils possess a zone of accumulation of salts in the profile, and depending on the nature and position of this zone in the profile, the alkalization and the consequent development of a structure profile take place. These genetic characteristics undoubtedly place these soils in the broad world group of 'alkali soils with structure' described by Glinka [1927].

(3) The causes of alkaline degradation of these black cotton soils have been traced to (*i*) great aridity of the tract combined with great soil depth, (*ii*) topographic situation which affects the surface soil due to salt washings from the surrounding catchment area, and (*iii*) nearness of saline subsoil water.

(4) The soil-forming processes leading to the alkalization of the profiles can be broadly divided into two groups for the purposes of assessing the suitability for perennial irrigation : (*a*) Processes responsible for the formation of a compact 'A' horizon but which at the same time help in the development of a porous and well-drained 'B' horizon ; (*b*) Processes which develop ultimately the compaction of both 'A' and 'B' horizons thus bringing into existence the worst types of alkali soils. These latter soils resemble more closely the 'Solonetz' soils while the former soils have more affinity with the 'Steppe' alkali soils.

(5) Since these alkali soils are formed as a result of extreme aridity in climate, creation of a humid condition by irrigation was thought essential for their reclamation. Experiments were, therefore, laid out on a typical alkali soil (with a porous 'B' horizon) on the farm to study the interaction of water, manure, cropping and fallowing on the soil colloids. Results indicate in a general way that all the above factors of cane-growing help in reducing sodium colloid and in increasing the proportion of calcium colloid, which are so essential for building up of desirable soil structures. Appreciable lowering in *p*H values was also observed in these cases.

(6) In the case of dry covered fallow it was noticed that a slight lowering in the Ca/Na ratio was followed by a rise in *p*H value. The harmful effect of dry fallowing was, therefore, apprehended which was further corroborated by detailed studies on the movement of soluble calcium and sodium salts in the profile. Summer fallowing was observed definitely harmful in this respect and the most effective means of checking it was found to be growing of irrigated crops like lucerne and *shevri* during this period.

(7) In the case of the worst type of alkaline soils (where the 'B' horizon is usually impervious) it may not be possible to grow any irrigated crop with success. In such cases it will be necessary to reclaim the soils by artificial methods. It was found that the best reclaiming agent for these soils is a mixture of sulphur and farmyard manure applied at the rate of half a ton and two tons per acre respectively. Molasses (10 tons per acre) was also found useful but it proved less effective when compared with the sulphur mixture. In alkaline soils showing impervious 'B' horizon provision for shallow drains appears to be essential when they are to be brought under perennial irrigation.

(8) When the soils at different stages of reclamation (as judged by Ca/Na ratios) were compared in a Neubauer's test for available potash and phosphoric acid it was noticed that the reclaimed soils were definitely superior in their available constituents when compared to partially reclaimed or unreclaimed soils. Similar superiority of the reclaimed soils was also observed in their microbiological activities as tested by the evolution of carbon dioxide from these soils.

(9) A pot-culture experiment with cotton indicated that a calcium/sodium ratio higher than 8·0 was essential for the proper growth and boll formation in cotton.

(10) The quality of *gul* was also found to be considerably improved when canes were grown in soils having a high Ca/Na ratio.

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A MOSAIC DISEASE OF BOTTLE GOURD

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(With Plates VII & VIII and two text-figures)

In May and June, 1941, during observations on the occurrence of diseases of vegetable crops in zamindars' fields round about Delhi, a mosaic disease of bottle gourd (*Lagenaria vulgaris* Ser.) was seen to occur commonly. Large number of plants were affected and the infection appeared to be widespread. The symptoms were more marked on younger leaves and the leaf surface showed a combination of dark green to pale green areas.

A large number of isolations made from the diseased material did not give any fungal or bacterial growth. Microscopic examination of the diseased tissue also did not reveal the presence of any organism. The nature of the symptoms of the disease and failure to isolate any organism from the diseased tissue suggested a virus as the cause.

Experiments conducted with a view to study the symptomatology, transmission and properties of the casual virus are reported in this paper.

Material and method

The original inoculum of bottle gourd mosaic virus was taken from a mature, fruit bearing, infected bottle gourd plant. Young bottle gourd plants grown under insect-proof conditions were infected by mechanical inoculation. Later on, transfers were made to young plants periodically in order to provide a stock of freshly infected plants for inoculation work throughout the course of the investigation.

The standard extract for inoculation was prepared by crushing to a fine pulp in pestle and mortar a known weight of young infected leaves which had previously been washed and dried in folds of filter paper adding a small quantity of water from time to time. To every gram of leafy material 1 c.c. of water was added. This was then pressed through muslin by hand.

Inoculations were carried out by dusting the leaves with finely powdered carborundum and smearing the leaf with a piece of absorbent cotton wool dipped in fresh extract from the diseased plant. This method usually gave 100 per cent infection. Controls were similarly treated except that extract from healthy plants was used as inoculum. Every care was taken to maintain aseptic conditions and all the apparatus used was sterilized according to requirements of each experiment.

FIG. 1. Infected and healthy leaves of bottle gourd

FIG. 2. Infected bottle gourd plant

FIG. 1. Infected bottle gourd plants

FIG. 2. Infected and healthy plants of bottle gourd of the same age (18 days) after inoculation

The plants raised in sterile soil under insect-proof conditions were as a rule inoculated when they had developed the first three to four true leaves and for any one experiment plants of the same age were employed so that the results could be strictly comparable. The test plants were always kept under observation for at least four weeks.

Symptoms of the disease

The symptoms of the disease produced on bottle gourd by mechanical inoculations in the insect-proof house were similar to those observed on plants growing in the cultivators' fields as well as our experimental plots exposed to normal infection. During the growing season, i.e. March to August, the first symptoms of infection in the insect-proof house appear six to eight days after inoculation but during winter months the infection may take 28 to 30 days or more. The growth of plants during these months is extremely slow. The best time for infection coincides with the optimum period for growth. The inoculated leaves seldom show signs of infection but the succeeding young leaves exhibit the first marked symptoms of the disease. Early symptoms are in the form of broad chlorotic streaks between the major veins along which a deep green portion persists. Later, however, the chlorotic portion gradually expands thus limiting the green portion to either side of the veins. Plate VII, fig. 1 shows a leaf of an infected and a healthy plant.

Young infected leaves may either be distorted with wavy and irregular outline or may have a wrinkled surface, or both. Occasionally, the mid-rib arches above the centre of the leaf surface with the result that the leaf apex as well as the margins are curled downwards. Characteristic dark green blisters occur commonly and are seen scattered over the entire pale green leaf surface. These appear as small convex areas on the upper surface of the leaf. They are the result of curving in of the lower surface of the leaf and are not due to the thickening of a portion of the leaf surface. These blisters are partly responsible for the wrinkled appearance of the leaves. Plate VII, fig. 2 and Plate VIII, fig. 1 show infected bottle gourd plants.

The infection is always systemic and all the succeeding leaves show symptoms of the disease in the form of chlorotic streaks, or quite often as irregular light green and dark green mottling in a limited portion or the whole surface of the leaf. Some leaves show complete chlorosis with dark green blisters, others exhibit regular mottling in the form of minute light green and dark green specks all over the leaf surface. In about seven weeks' time the older leaves dry up and are shed. The plants infected early in the season remain small in size, blossom sparingly and set fewer fruits which are usually normal.

Twelve healthy plants 20 days old and of the same size were selected. Six were infected with bottle gourd virus and six were kept as controls. The growth of the plants regarding their height, leaf area, size and number of internodes and size of petioles 16 days after infection and of the control plants are compared in Table I. The statistical significance of the differences in different parts of healthy and diseased plants recorded were evaluated by Bessel's method [Shaw, 1936]. In this method a ratio of the difference of the two means to the probable error of the difference is calculated from the data and according as this is a greater or smaller number, the greater or smaller is the probability that the results recorded are significant. When the ratio

M. D./P. E. D. is just above 3·2 the results are on the margin of significance. The ratio M. D./P. E. D. for all the comparisons shown in Table I lies between 6 and 12. This represents an enormously high probability that the height, number and area of leaves, number and size of internodes and size of petioles is significantly greater in healthy plants. Plate VIII, fig. 2 shows healthy and infected plants of the same age 18 days after inoculation.

Table I

Effect of infection on growth of different organs of plant

Plant No.	Height of plants (in.)		Leaf				Internodes				Petioles	
			Total number per plant		Average area per leaf in square inches		Total number per plant		Mean size per plant (in.)		Mean size per plant (in.)	
	Healthy	Diseased	Healthy	Diseased	Healthy	Diseased	Healthy	Diseased	Healthy	Diseased	Healthy	Diseased
1	16·5	11·0	8	6	4·31	2·89	5	4	2·14	1·42	1·45	1·01
2	30·0	12·0	11	6	6·86	2·51	8	3	3·18	1·90	1·35	1·08
3	26·0	9·4	8	6	5·41	1·43	6	3	3·26	1·07	1·67	0·77
4	20·0	10·5	8	6	4·10	2·94	5	2	2·86	0·98	1·15	0·94
5	15·5	14·5	9	7	3·27	3·02	5	5	2·32	1·98	1·46	1·12
6	38·5	11·5	12	6	6·80	3·31	9	4	3·81	1·30	1·36	1·05
P. E. D.	1·6188		0·5034		0·2743		0·3561		0·1268		0·0364	
M. D./P. E. D.	7·9		6·2		8·9		7·8		11·7		11·2	

Internal structure. Vertical sections of leaves both from healthy and diseased plants were cut and examined microscopically. Leaves from the plants of the same age and approximately from same position were taken.

Epidermis of the diseased leaves may remain unaffected but in leaves which show wrinkling and puckering the epidermal layer is not regular and well defined but shows some depressions and eruptions. Size and shape of palisade cells is markedly affected. They become more broad than long and are

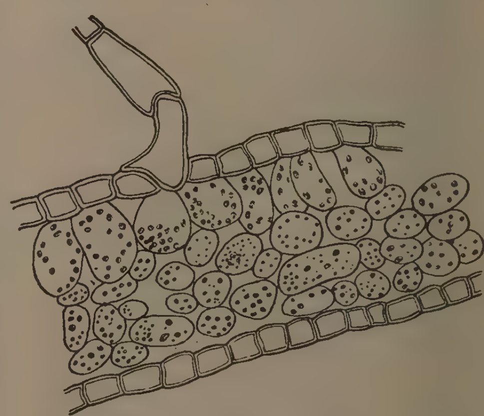

Fig. 1. Vertical section of infected bottle gourd leaf ($\times 304$)

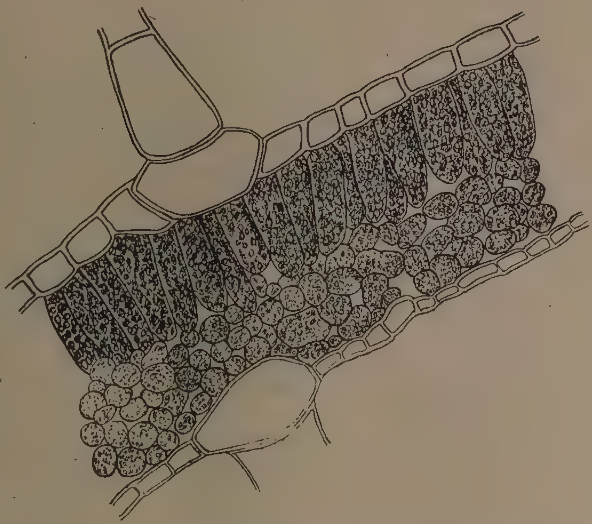

FIG. 2. Vertical section of healthy bottle gourd leaf (×304)

more or less cuboid in shape and are loosely arranged as compared to those in healthy leaves where they are greater in length and are compactly arranged. The chloroplasts in the palisade cells of infected leaves are few in number. They either aggregate in the centre of the cell or in a corner or may be arranged along the walls of the cells so that the remaining portion of the cell appears almost empty and colourless. The chloroplasts are sometimes evenly distributed in the cell. In healthy leaves the cells are almost completely filled with the chloroplasts.

The spongy parenchyma in the diseased leaves is loosely arranged and the cells appear to be a little larger in size.

The chlorotic portion of a diseased leaf is slightly thinner than the deep green portion, including the green blisters of the same leaf or any part of a healthy leaf.

There is no appreciable difference in the internal structure of green blisters of diseased leaves and any portion of a green healthy leaf. Figs. 1 and 2 show vertical sections through an affected and a healthy leaf respectively.

HOST RANGE

With a view to determine the host range of the virus other cucurbits in addition to bottle gourd were tested. This included cucumber, bitter gourd, melon, water-melon and vegetable marrow. Inoculations were carried out by the method already described on young plants grown in the insect-proof house. The symptoms produced on these hosts are described below.

Cucumber (*Cucumis sativus* L.). Symptoms appear about 10 days after inoculation. The inoculated leaves do not show any symptoms of the disease. The first visible symptom is the clearing of veins and the subsequent leaves either show mild chlorosis of the whole leaf with green blisters, the number of which varies greatly, or crumpled and wrinkled condition with chlorosis or mottling limited to the margins or the veins. The growth of the infected plants is adversely affected.

Bitter gourd (*Momordica charantia* L.). The first symptoms are observed only on the youngest leaves about eight days after inoculation. There is no clearing of veins but the leaves show regular light green and dark green mottling over the whole leaf surface. In addition to the mottling, sometimes there is a darkening of the central portion which is usually limited to either side of the

mid-rib. The typical blisters formed on bottle gourd or cucumber are, however, absent.

Melon (*cucumis melon* L.). The symptoms are visible about eight days after inoculation. The first obvious symptom is the clearing of veins of the older leaves. Later the young leaves show light mottling which in some leaves is in the form of a regular pattern. The mottling may cover the whole portion of the leaf or may be restricted to a particular portion. The infected leaves may or may not be crumpled.

Water-melon (*Citrullus vulgaris* Schrad). The infection does not occur so readily and the first symptoms appear approximately after 17 days. The youngest leaves show light mottling which is in the form of light green and dark green spots almost uniformly distributed over the whole surface. There is no wrinkling and distortion of the leaves. The symptoms are not much pronounced.

Vegetable marrow (*Cucurbita pepo D. C.*). The symptoms are first visible on younger leaves only. These show clearing of veins. Mottling usually starts at the apex and progresses inwards. In addition, small almost circular chlorotic spots develop which tend to fade when greater portion of the leaf becomes chlorotic. The subsequent leaves also show vein clearing together with apical and marginal chlorosis. Some leaves exhibit severe blistering or puckering between the veins as in the case of bottle gourd, others show downward curling of leaf margin and apex.

In some plants, however, the first infected leaf may show vein clearing and excessive blistering between the veins but no chlorosis. The affected leaves do not show much distortion.

Repeated efforts to transmit the disease to solanaceous plants such as tomato (*Lycopersicum esculentum* Mill. var. Suttons' Early Market), Jimson weed (*Datura Stramonium* L.), pepper (*Capsicum annuum* L.), petunia (*Petunia hybrida* Vilm.) and tobacco (*Nicotiana tabacum* L. var. White Burley) were unsuccessful. In addition, cowpea [*Vigna unguiculata* (L.) Walp.], both black seeded and ordinary, and soybean (*Glycine hispida* Maxim.) remained free from any symptoms of the disease when inoculated with standard extract prepared from diseased bottle gourd leaves.

Properties of the virus

Longevity in vitro. Pure juice prepared from the diseased bottle gourd leaves was divided into several lots of 5 c.c. each in test tubes which were stored in the laboratory. Young healthy bottle gourd plants were inoculated with samples of the stored juice at intervals of 24, 48, 72 and 96 hours. The temperature of the laboratory ranged between 28° and 37°C. during the experimental period. The fresh juice was tested for its infectivity prior to storage. Controls were run side by side in each case by inoculating plants with the freshly extracted juice.

All the stored samples of the juice failed to infect and produce any symptoms of the disease showing thereby that within a period of 24 hours at laboratory temperature the juice is rendered non-infectious.

In a similar experiment pure juice was replaced by standard extract which was stored at laboratory temperature as well as at 20°C. for similar periods, i.e. 24 to 96 hours but in every case the extract failed to bring about infection,

In another experiment standard extract from diseased bottle gourd plants was stored at room temperature (20° to 23·3°C. during the day) from 2 to 24 hours and the stored extract tested on young bottle gourd plants. The results are given in Table II.

TABLE II

Effect of storage of virus at room temperature

Experiment	Storage period	Number of plants	
		Inoculated	Infected
I	Fresh standard extract	2	2
	2½ hours	3	3
	4½ "	3	2
	6 "	4	0
	8 "	3	0
	24 "	2	0
II	Fresh standard extract . . .	3	3
	24 hours	3	0
	48 "	3	0
	72 "	3	0
	96 "	3	0

The results given above show that the standard extract is rendered innocuous after being stored for six hours at room temperature.

When the standard extract was stored at 5°C. for 24, 48, 72 and 96 hours it was observed that after 96 hours storage the extract failed to bring about infection. It partially retained its infectivity after 72 hours, and gave 100 per cent infection after 24 hours, storage.

Desiccation. The leaves of infected bottle gourd plants were dried at room temperature for a week and the extract prepared by grinding the leaf tissue which had previously been soaked in water in a pestle and mortar. To every gram of the dried material 2 c.c. of water was added. The crushed material was then pressed through muslin. The extract thus prepared failed to infect young bottle gourd plants.

Thermal inactivation. Standard extract prepared from young diseased leaves of bottle gourd was divided into six samples of 5 c.c. each in thin walled glass test tubes of uniform size and capacity. Samples of the standard extract were exposed to 45°, 50°, 55°, 60° and 65°C. for 10 minutes in a water-bath,

Care was taken that the portion of the tube containing the extract was completely immersed in water. The samples of extract immediately after exposure to the above temperatures were dipped in cold water. Bottle gourd plants (24 days old) were inoculated with the samples of extract thus exposed and with unheated extract which served as check. The results of a typical experiment are given in Table III.

TABLE III

Thermal inactivation of the virus

Exposure temperature °C.	Plants inoculated	Plants infected
Untreated check	4	4
45	4	4
50	4	1
55	4	1
60	4	0
65	4	0

The results given above show that the activity of the virus falls considerable when exposed to 50°C. whereas no infections are obtained with the virus exposed to 60°C. or higher. In 60° and 65°C. lots no symptoms of infection appeared even 31 days after inoculation.

Effect of chemicals. Effect of 50 per cent alcohol, acetone and chloroform on the standard extract prepared from diseased bottle gourd plants was determined by adding 5 c.c. of the above chemicals to 5 c.c. of the standard extract. Samples of extract thus treated and the untreated control to which 5 c.c. distilled water had been added were shaken for 10 minutes and young healthy bottle gourd plants inoculated with different samples. The inoculated plants were kept under observation for four weeks. Extracts treated with alcohol and acetone appeared to have lost their activity, as they failed to cause infection, whereas the control extract reproduced typical disease within 11 days. Bottle gourd plants inoculated with extract treated with chloroform produced a burning effect on the plants so that it was difficult to read the symptoms.

Inoculations of healthy bottle gourd plants with standard extract of diseased bottle gourd plants containing various strengths of mercuric chloride showed that the virus is inactivated by mercuric chloride in a strength of 1 : 5000. The results of such an experiment are given in Table IV.

Toleration to dilution. Leaves of young bottle gourd plants (15 days old) were inoculated with freshly extracted pure juice from diseased plant leaves as well as with juice diluted with sterilized distilled water in order to determine the effect of dilution on infectivity of the juice. The results of three typical experiments are set out in Table V.

TABLE IV

Effect of mercuric chloride on the activity of the virus

Strength of mercuric chloride	Number of plants	
	Inoculated	Infected
Nil (Standard extract full strength control)	6	6
Nil (Standard extract diluted with water 50 : 50 control)	6	6
1 : 10,000	6	5
1 : 5,000	5	0
1 : 2,000	6	0
1 : 1,000	4	0

TABLE V

Effect of dilution on infectivity

Dilution	Experiment I Number of plants		Experiment II Number of plants		Experiment III Number of plants	
	Inoculated	Infected	Inoculated	Infected	Inoculated	Infected
Nil (control)	3	3	4	4	4	4
1 : 10	3	3	—	—	—	—
1 : 50	3	2	—	—	—	—
1 : 100	3	1	4	2	4	4
1 : 500	—	—	4	0	3	0
1 : 1,000	—	—	4	0	3	0
1 : 2,000	—	—	4	0	3	0
1 : 3,000	—	—	4	0	—	
1 : 4,000	—	—	4	0	—	—
1 : 5,000	3	0	4	0	—	—
1 : 10,000	3	0	—	—	—	—

— denotes not tested

The results show that the virus is completely inactivated at and above dilutions of 1 : 500.

Filterability. Standard extract prepared from diseased bottle gourd plants was filtered through filter paper, filter paper impregnated with diatom dust and Pasteur Chamberland filters of grades L_1, L_3 and L_5. In the case of Chamberland filters the filtrations were always carried out under reduced pressure of 1/5 atmospheric. Infectivity of the filterates was tested on young healthy bottle gourd plants in the insect-proof house.

The experiment with each of the above filters was repeated at least three times. Typical results are recorded in Table VI.

TABLE VI

Filterability of bottle gourd virus

Experiment	Date	Inoculum	Number of plants	
			Inoculated	Infected
I	14 Aug. 1941	1. Unfiltered standard extract .	2	2
		2. Filtered standard extract—		
		(*a*) Filter paper (Whatman's 2) filtrate	4	1
		(*b*) Filter paper impregnated with diatom dust filtrate .	4	Nil
II	20 Aug. 1941	1. Unfiltered standard extract .	4	4
		2. Filtered standard extract—		
		(*a*) Filter paper (Schutz 613) filtrate	6	1
		(*b*) Chamberland Candle L_1 filtrate	4	Nil
		(*c*) Chamberland Candle L_3 filtrate	4	Nil
		(*d*) Chamberland Candle L_5 filtrate	2	Nil
III	11 Dec. 1941	1. Unfiltered standard extract .	3	3
		2. Filtered standard extract .		
		(*a*) Filter paper (Schutz 613) filtrate	6	Nil
		(*b*) Chamberland Candle L_1 filtrate	5	Nil
		(*c*) Chamberland Candle L_3 filtrate	5	Nil

The results given in Table VI show that the standard extract from infected bottle gourd plants during passage through filter paper loses a greater part of its active infective principle. The virus fails to pass through Chamberland filters of different grades, i.e. L_1 to L_5 and even through filter paper impregnated with diatom dust.

Transmission. Bottle gourd mosaic virus is readily transmissible by the sap. An experiment was conducted to find out whether the virus is transmissible through seed. A few young healthy bottle gourd plants growing in the insect-proof house were infected with the virus and transplanted in an open field when the infection had become systemic. The seeds of fruits borne by such plants were collected and sown in pots. Over 200 plants raised from seeds of diseased plant fruits appeared to be normal and remained free from any symptoms of the disease showing thereby that the transmission of the disease through seed does not occur.

From the observations recorded in this paper it is evident that bottle gourd mosaic is a virus disease and is readily transmissible by mechanical inoculation with sap. The host range of the virus appears to be narrowly restricted. The virus fails to pass through Chamberland filters or filter paper impregnated with diatom dust. Infectivity of the virus is lost within six hours when stored at room temperature (20°—23·3°C.). Exposure to 60°C.

for 10 minutes renders it non-infectious. The virus is completely inactivated at a dilution of 1 : 500. Inactivation of the virus is also brought about by 50 per cent alcohol or acetone in 10 minutes and by mercuric chloride in a strength of 1 : 5000.

Bottle gourd virus is similar to *Cucumis* virus 1 [Doolittle, 1920] regarding filterability through Chamberland filters and thermal-death-point but differs regarding its host range, longevity *in vitro* and dilution-end-point. The virus like *Cucumis* virus 2 [Bewley, 1926] is unable to infect solanaceous plants but differs from *Cucumis* virus 2 in all other important properties.

It is proposed to call the bottle gourd mosaic virus *Cucumis* virus 3 (Smiths' classification). The properties of the three viruses are compared in Table VII.

TABLE VII

Properties of the Cucumis viruses compared

	Cucumis virus 1	*Cucumis virus* 2	Bottle gourd virus
Longevity in vitro (room temperature)	72 to 96 hours	One year or longer	Six hours
Filterability (Chamberland filters)	Not filterable	Filterable	Not filterable
Thermal inactivation	60° and 70°C.	90°C.	60°C.
Dilution-end-point	1 : 10,000	Not recorded	1 : 500
Resistance to 50 per cent alcohol	Inactivated in one hour	Not inactivated in one hour	Inactivated in 10 minutes
Infection of solanaceous plants	+	—	—
Infection of cowpea	+	—	—
Infection of vegetable marrow	+	—	+

\+ = positive — = negative

SUMMARY

A new virus disease of bottle gourd (*Lagenaria vulgaris* Ser.) is described.

The virus has a limited host range and is highly sensitive so much so that storage for six hours at room temperature renders it innocuous. The virus loses infectivity at a dilution of 1 : 500 and exposure to 60°C. for 10 minutes is sufficient to destroy the infective principle. The virus is held back during passage through Chamberland filters and its infectivity is greatly impaired during passage through filter paper. It is proposed to call the virus *Cucumis virus* 3.

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STUDIES ON THE COTTON JASSID (*EMPOASCA DEVASTANS* DISTANT) IN THE PUNJAB

III. EFFECT OF JASSID INFESTATION ON THE DEVELOPMENT AND FIBRE PROPERTIES OF THE COTTON PLANT*

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IN the previous two publications of this series [Varma and Afzal, 1940 and Afzal, 1941] the development of the pest on different varieties of cotton and the methods used in breeding resistant varieties were discussed. It is now proposed to examine in some detail the effect of jassid attack on the cotton plant.

Literature on this aspect of the problem is very scanty. We have been able to find only two references on this subject. The first one is that of Parnell [1925-26] who mentions in general terms that 'with the reddening of the plant, development ceases, squares and very young bolls are shed, partly developed bolls dry up and only those that are nearing maturity ripen off and open naturally. A certain proportion of the latter always produces weak lint, due to their development having been arrested at too early a stage'. Sloan [1938] also mentions the retardation of plant development and shedding of buds and young bolls with the jassid attack. 'Immature bolls develop poorly and produce wasty lint......In a mild outbreak......the quality of lint is not as good as that from uninfested plants'. Figures are not, however, given by either of the authors and it is difficult to picture the extent of the damage done to the plant. It was, therefore, considered necessary to assess the extent of damage done by jassids to the development and the fibre properties of the cotton plant grown at Lyallpur.

MATERIAL AND METHODS

This study was carried out by growing plants in jassid-proof cages. As the number and size of cages was limited, in the beginning only a few plants of one variety could be grown in one year. During 1940, however, more and bigger cages were employed and the number of varieties and plants under experiment were consequently increased.

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During 1938, six plants of 38F, a highly susceptible variety of Punjab-American cotton, were raised in each of the two cages. One cage was kept free of infestation and in the other a very high degree of infestation was maintained throughout the season by artificially liberating a large number of jassid nymphs. During 1939, the same procedure was adopted for a highly resistant variety, namely P-A 289F/43. The only difference was that this year four plants were grown in each cage. The size of the cages in these two years was 6 ft. × 6 ft. × 6 ft. During 1940, the experiment was repeated with two susceptible (38F and 289F/K.25) and two highly resistant (289F/43 and L.S.S) varieties of Punjab-American cotton. Four plants of each of these varieties were grown in jassid proof cages (6 ft. × 6 ft. × 6 ft.) and kept free of any attack while about 20 plants of these varieties were grown in other cages (size 16 ft. × 16 ft. × 8 ft.) where the infestation was kept up artificially as before. Since these latter cages were much bigger than the jassid proof cages they may have proved of some advantage to the plants grown in them The plan of the experiment is given in Table I.

TABLE I

Plan of the experiment

Year	Variety	Resistant or susceptible to jassids	Number of plants in	
			Cage kept free of infestation	Cage infested with jassids
1938	38F . . .	Susceptible .	6	6
1939	P-A 289F/43 .	Resistant . .	4	4
1940	38F . . .	Susceptible .	4	21
	P-A 289F/43 .	Resistant . .	4	21
	P-A 289F/K.25	Susceptible .	4	22
	P-A L.S.S .	Resistant . .	4	20

Sowing was done towards the end of May each year and both the cages were treated alike for all cultural operations. Artificial infestation was started from about the middle of July and continued up to about the end of October each year and a jassid population of about 200 to 300 nymphs per plant was maintained throughout this period.

Records of weekly growth in height of the main stem and the daily rate of flower and boll production were maintained during 1938 and 1939. No such data are available for 1940. The produce of each plant was picked

and ginned separately for each year and the ginning outturn was calculated. The fibre properties were also determined.

The various records will now be dealt with in detail, but it should be mentioned at the very outset that as the plant population was small, the experimental error may be expected to be high. The very high cost of jassid proof cages did not allow us to deal with a larger number of plants. In the case of development records a further drawback arose in that data for only two years were available.

Results

Growth in height

The weekly growth in height of both the varieties in the infested and the jassid-free cages was measured. The figures along with their statistical interpretation are given in Table II.

Although the records on the susceptible and the resistant varieties were taken in two different years, yet certain interesting deductions could be made from Table II. By applying the equation $H = Ae^{bt}$ [Afzal and Iyer, 1934], we find that the relative rate of growth 'b' was significantly smaller in the infested plants of the susceptible variety (38F) than in those kept free while in the case of the resistant variety (289F/43) there was no such difference. Thus it will be seen that whereas a heavy infestation of jassids on a susceptible variety significantly reduced its rate of growth, an apparently equally high infestation on a resistant variety had no such effect. It must, however, be stressed that the ideal plan would have been to perform these experiments on the susceptible and the resistant varieties in the same season. Since the two varieties were grown in two different years, the effect of the seasonal factors cannot be easily brought out.

Flower and boll production

The flower and boll counting was done every day and the results are summarized in Table III.

Here again it will be seen that the differences in the number of flowers and bolls produced in the case of infested and free plants of the susceptible variety were statistically significant ; the infested plants produced a definitely smaller number of flowers and bolls than those kept free of attack. In the case of the resistant variety, on the other hand, there was no significant difference in the number of flowers and bolls produced by the infested and the free plants. The difference in the shedding percentage of bolls was non-significant in both the cases.

The *kapas* (seed cotton) picked from each plant was weighed and ginned separately and the average weight of *kapas* per boll and the ginning outturn were determined in each case. It will be seen from Table III that in the case of the susceptible variety, although there was no statistical difference in the average weight of *kapas* per boll, the shedding percentage and the ginning outturn of the infested and the free plants, the total amount of *kapas* per plant was, however, significantly more in the free plants. In the case of the resistant variety there was no such difference in any of these three characters between the infested and the free samples.

TABLE II

Average increase in height (cm.) of infested and free plants in 1938 and 1939

Week ending	1938-Variety-38F susceptible to jassids Average for plants in cage		1939-Variety-289F/43 resistant to jassids Average for plants in cage	
	Free	Infested	Free	Infested
Initial height on— July 5	14·8	20·9	66·1	54·9
July 12	8·9	6·6	..	..
July 18	13·5	8·1	..	..
July 25	13·0	7·5	14·5	14·8
August 1	11·2	6·6	9·0	6·2
August 8	11·4	5·4	13·6	7·5
August 15	10·3	5·8	14·8	7·7
August 22	11·4	4·5	14·1	4·3
August 29	11·8	5·0	12·5	7·8
September 5	17·0	8·3	8·6	12·3
September 12	16·5	13·4	10·9	12·3
September 19	9·1	9·7	9·0	5·5
September 26	8·7	6·4	8·8	4·1
October 3	13·4	11·2	4·7	1·4
October 10	6·7	8·4	..	..
October 17	7·3	3·3	..	..
Mean	11·35	7·35	10·95	7·63
Total height attained (cm.)	185·0	131·1	186·6	138·8
Equation $[H = Ae^{bt}]$	$23·35e^{0·1499t}$	$24·76e^{0·1140t}$	$69·07e^{0·0928t}$	$58·05e^{0·0811t}$
Relative growth rate 'b'	0·1499	0·1140	0·0928	0·0811
S. E. of 'b'	±0·01386	±0·006242	±0·006678	±0·005293

TABLE III

Flower and boll production

Nature of infestation	Plant No.	1938—Susceptible variety (38F)						1939—Resistant variety (289F/43)					
		Total No. of flowers	Total No. of bolls	Shedding per centage	Average weight of *kapas* per boll (gm.)	Total weight of *kapas* (gm.)	Ginning outturn	Total No. of flowers	Total No. of bolls	Shedding per-centage	Average weight of *kapas* per boll (gm.)	Total weight of *kapas* (gm.)	Ginning outturn
Infested—	1	38	7	81·5	2·23	15·6	26·9	36	6	83·3	3·05	18·30	26·50
	2	27	7	74·0	2·44	17·1	26·3	31	4	87·1	2·68	10·72	27·93
	3	43	10	76·7	1·95	19·5	25·7	14	4	71·4	2·04	8·17	29·49
	4	28	4	85·7	4·08	16·3	23·9	43	7	87·7	2·84	19·9	29·54
	5	49	9	81·6	3·24	29·2	28·4	...	...	...	...	...	...
	6	18	5	72·2	3·64	18·2	23·6	...	...	...	...	...	...
Free—	1	55	11	80·0	2·98	32·8	27·5	59	11	81·3	2·55	28·08	27·77
	2	65	12	81·5	2·24	26·9	24·9	26	8	69·2	2·67	21·39	26·22
	3	85	23	72·9	2·88	66·3	26·9	20	7	65·0	2·88	20·16	27·13
	4	53	19	64·1	3·17	60·4	27·4	20	6	70·0	2·59	15·54	32·49
	5	50	14	72·0	2·27	31·8	28·1	...	...	...	...	...	...
	6	76	19	76·0	3·35	63·7	29·8	...	...	...	...	...	...
Difference of means		+30·17	+9·33	—4·20	—0·115	+27·66	+1·63	+0·25	+2·75	—11·00	+0·020	+7·02	+0·038
Value of '*t*'		4·072*	4·361*	1·263	0·291	3·576*	1·646	0·022	2·0913	2·138	0·087	1·822	

* Indicates significance at 1 per cent level

Fibre properties

From the 1938 experiment, 12 samples of lint of 38F, six from the control and six from the infested cages were available for tests for fibre characters. In 1939, there were 8 samples of lint of P-A 289F/43, four from the control cage and four from the infested one. In 1940, whereas samples of lint from 4 plants each of the Punjab-American varieties: 38F, 289F/K.25, 289F/43 and L S.S., from the control cages were available, the number of samples of lint available from the cages infested with jassids were 21 from 38F, 22 from 289F/K.25, 21 from 289F/43 and 20 from L.S.S. (Table I). The disparity in the numbers of samples from the control and infested cages was too high and, to reduce this disparity, lots were drawn choosing perfectly at random six samples from the infested cage in each of the above-mentioned four varieties.

All these samples were tested for the following fibre-characters.

(*a*) Mean fibre length
(*b*) Modal length
(*c*) Fibre-length irregularity (per cent)
(*d*) Mean fibre-weight per unit length
(*e*) Percentage of mature fibres, and
(*f*) Highest standard warp counts.

The methods followed in the determination of the first four characters were the same as described by Ahmad [1933] and in the determination of the percentage of mature fibres, the method of Gulati and Ahmad [1935] was adopted using their new device for mounting fibres [Ahmad and Gulati, 1936]. The first five fibre-characters were converted into a quantity highest standard warp count (H.S.W.C.) according to an equation given by Ahmad [1941]. The H.S.W.C. serves to indicate in a single term the spinning quality of a cotton. However, as in the present case, it was not determined as the result of actual spinning tests but was calculated from the fibre-properties, the value obtained should be ragarded as approximately correct. These data are presented in Table IV.

The differences in the average values of fibre-characters of samples of lint from the control and the jassid-infested cages were examined for statistical significance by the Student's 't' method [Fisher, 1932]. The average values of fibre-characters in samples from the control and jassid-infested cages, the differences between them, the corresponding 't' values and their significances are brought out in Table V.

In the case of 38F, a variety highly susceptible to attack by jassids, it was found in the 1938 experiment that the mean and modal lengths in samples from the jassid-infested cage were significantly lower than those in samples from the control cage. The fibre-length irregularity was similarly higher in samples from the infested cage. The mean fibre-weight per unit length and percentage of mature fibres were not significantly different from one another even though the samples from the control cage recorded uniformly higher values for these characters. The calculated H.S.W.C. in samples from the control cage was significantly greater than in samples from the infested cage. On the whole, it could be stated that the quality of lint in samples from the control cage was better than that in the infested cage.

TABLE IV

Year	Variety	Control cage							Infested cage						
		Plant No.	Mean fibre-length (cm.)	Modal length (cm.)	Fibre-length irregularity (per cent)	Mean fibre-weight per unit length 10^{-6} gm./cm.	percentage of mature fibres	H.S.W.C. (calculated)	Plant No.	Mean fibre-length (cm.)	Modal length (cm.)	Fibre-length irregularity (per cent)	Mean fibre-weight per unit length 10^{-6} gm./cm.	Percentage of mature fibres	H.S.W.C. (calculated).
1938	P-A 38F .	1	2·55	2·92	20·9	1·69	58	44·1	1	2·30	2·65	23·5	1·77	48	35·6
		2	2·35	2·68	23·2	1·34	23	39·9	2	2·34	2·66	24·8	1·63	55	38·9
		3	2·52	2·95	23·0	1·70	61	44·8	3	2·19	2·37	25·4	1·30	41	36·5
		4	2·49	2·81	21·2	1·72	59	42·3	4	2·35	2·62	24·1	1·53	49	39·9
		5	2·33	2·63	23·2	1·42	50	40·7	5	2·39	2·72	24·7	1·69	66	40·1
		6	2·42	2·72	19·6	1·67	50	40·4	6	2·30	2·66	25·5	1·54	41	37·7
1939	P-A 289F/43 .	1	2·50	2·72	17·6	1·64	63	45·0	1	2·53	2·88	22·5	1·99	71	41·3
		2	2·43	2·72	25·4	1·53	43	41·3	2	2·42	2·70	24·9	1·55	52	41·9
		3	2·50	2·74	21·6	1·46	36	43·7	3	2·37	2·60	20·1	1·47	49	41·0
		4	2·33	2·45	17·3	1·60	47	38·3	4	2·54	2·75	18·6	1·64	59	44·7
1940	P-A 38F .	1	2·07	2·20	25·8	1·56	57	32·1	2	2·15	2·19	22·9	1·62	43	32·1
		2	2·23	2·44	24·3	1·93	76	33·7	3	2·12	2·22	23·7	1·56	36	31·9
		3	2·25	2·50	25·2	1·90	76	34·6	6	1·89	1·87	18·4	1·46	39	26·7
		4	2·19	2·23	21·3	1·88	78	33·2	13	2·11	2·21	23·0	1·77	55	30·3
									18	2·11	2·22	23·4	1·71	47	30·4
									21	1·97	1·92	15·8	1·67	67	28·5
1940	P-A 289F/K.25	1	2·12	2·25	23·9	1·71	58	31·9	2	2·20	2·46	23·7	1·90	55	31·5
		2	2·24	2·48	26·4	1·67	49	35·0	9	1·97	2·09	16·1	1·93	44	22·7
		3	2·43	2·80	26·5	1·73	53	40·1	12	2·09	2·25	27·7	1·36	26	33·2
		4	2·30	2·61	21·6	1·55	43	37·3	13	2·02	2·14	24·6	1·43	26	28·8
									15	2·22	2·45	23·9	1·52	48	36·5
									22	1·89	1·89	16·4	1·20	6	26·0
1940	P-A 289F/43 .	1	2·40	2·74	29·8	1·37	34	42·3	3	2·49	2·77	22·7	1·62	52	42·9
		2	2·37	2·71	25·2	1·66	47	38·9	5	2·53	2·83	26·3	1·66	45	43·5
		3	2·22	2·47	26·7	1·85	46	32·2	6	2·40	2·66	25·7	1·87	57	37·8
		4	2·24	2·30	21·9	1·43	39	37·0	15	2·42	2·69	26·9	1·77	58	39·7
									19	2·50	2·85	26·0	1·84	66	41·9
									23	2·11	2·21	21·5	1·78	49	31·6
1940	P-A L.S-S. .	1	2·28	2·60	25·0	1·50	47	37·3	1	2·18	2·40	19·9	1·73	55	33·1
		2	2·34	2·61	22·7	1·69	53	37·7	2	2·28	2·52	19·3	1·90	79	35·6
		3	2·20	2·44	25·6	1·18	13	37·0	5	2·20	2·38	18·0	2·08	69	30·4
		4	2·17	2·37	22·6	1·52	35	33·8	16	2·37	2·62	20·3	1·62	56	39·9
									19	2·04	2·22	13·7	1·82	51	27·5
									20	2·27	2·56	23·6	1·63	42	35·5

TABLE V

Variety	Fibre-character	Infested cage: No. of samples	Infested cage: Average value	Control cage: No. of samples	Control cage: Average value	Difference in average values (Col. 4—col. 6)	D. F.	't'	Infested cage: No. of samples	Infested cage: Average value	Control cage: No. of samples	Control cage: Average value	Difference in average values (Col. 11—col. 13)	D. F.	't'
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		1938							1940						
P-A 38F	Mean fibre-length (cm.)	6	2·31	6	2·44	—0·13	10	2·825*	6	2·06	4	2·18	—0·13	8	2·052
	Modal length (cm.)	6	2·61	6	2·79	—0·18	10	2·370*	6	2·10	4	2·34	—0·24	8	2·318*
	Fibre-length irregularity (per cent)	6	24·6	6	21·8	+2·8	10	4·070†	6	21·2	4	24·1	—2·9	8	1·589
	Mean fibre-weight per unit length (10^{-6} gm./cm.)	6	1·58	6	1·59	—0·01	10	0·137	6	1·63	4	1·82	—0·19	8	2·094
	Percentage of mature fibres	6	49·9	6	50·3	—0·4	10	0·060	6	47·8	4	71·7	—23·9	8	3·393†
	Highest standard warp counts (calcu ated)	6	38·1	6	42·0	—3·9	10	3·488†	6	30·0	4	33·4	—3·4	8	3·014*
		..							1940						
P-A 289F/K. 25	Mean fibre-length (cm.)								6	2·06	4	2·27	—0·21	8	2·480*
	Modal length (cm.)								6	2·21	4	2·53	—0·32	8	2·217
	Fibre-length irregularity (per cent)								6	22·1	4	24·6	—2·5	8	0·980
	Mean fibre-weight per unit length (10^{-6} gm./cm.)								6	1·56	4	1·66	—0·11	8	0·700
	Percentage of mature fibres								6	34·2	4	50·8	—16·6	8	1·728
	Highest standard warp counts (calculated)								6	29·8	4	36·1	—6·3	8	2·169

N.B.—* Indicates significance at 5 per cent level
† Indicates significance at 1 per cent leve

TABLE V—*contd.*

Variety	Fibre-character	Infested cage: No. of samples	Infested cage: Average value	Control cage: No. of samples	Control cage: Average value	Difference in average values (Col. 4—col. 6)	D. F.	't'	Infested cage: No. of samples	Infested cage: Average value	Control cage: No. of samples	Control cage: Average value	Difference in average values (Col. 11—col. 13)	D. F.	't'
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		1939							1940						
P-A 289F/43	Mean fibre-length (cm.)	4	2·46	4	2·44	+0·02	6	0·381	6	2·41	4	2·31	+0·10	8	1·164
	Modal length (cm.)	4	2·73	4	2·66	+0·07	6	0·829	6	2·67	4	2·55	+0·12	8	0·775
	Fibre-length irregularity (per cent)	4	21·5	4	20·5	+1·0	6	0·445	6	24·8	4	25·9	—1·1	8	0·612
	Mean fibre-weight per unit length (10^{-6} gm./cm.)	4	1·66	4	1·56	+0·10	6	0·865	6	1·76	4	1·58	+0·18	8	1·780
	Percentage of mature fibres	4	57·7	4	47·2	+10·5	6	1·390	6	54·5	4	41·5	+13·0	8	2·882*
	Highest standard warp counts (calculated)	4	42·2	4	42·1	+0·1	6	0·088	6	39·6	4	37·6	+2·0	8	0·699
		......							1940						
P-A. L.S.S.	Mean fibre-length (cm.)								6	2·22	4	2·25	—0·024	8	0·372
	Modal length (cm.)								6	2·45	4	2·50	—0·05	8	0·625
	Fibre-length irregularity (per cent)								6	19·1	4	24·0	—4·8	8	2·740*
	Mean fibre-weight per unit length (10^{-6} gm./cm.)								6	1·80	4	1·47	+0·32	8	2·633*
	Percentage of mature fibres								6	58·7	4	37·0	+21·7	8	2·236
	Highest standard warp counts (calculated)								6	33·7	[illegible]	36·4	—2·8	8	1·192

N.B.—*Indicates significance at 5 per cent level

Repeating the experiments in 1940, it was found that the mean fibre-length in samples from the control cage was higher than in samples from the infested cage, though the '*t*' value of the difference in the two average values was just a little lower than that for the 5 per cent level of significance. The trend of the difference being in the same direction as in 1938, this difference can also be considered as significant. The modal length and percentage of mature fibres of samples from the control cage were significantly greater than in samples from the infested cage and the mean fibre-weight per unit length was higher in the control cage than in the infested one, the '*t*' value of the difference in this case also being just lower than that for the 5 per cent level of significance. The fibre-length irregularity percentage was not significantly different in samples from the control and infested cages. The calculated H.S.W.C. in samples from the control cage was significantly higher than that in samples from the infested cage. The above study leads, therefore, to the conclusion that in P-A 38F, highly susceptible to jassid attack, the quality of lint deteriorates significantly due to attack by jassids.

This observation was further corroborated by the study in 1940 of the fibre-characters of P-A 289F/K. 25, also highly susceptible to attack by jassids. The mean fibre-length in samples from the infested cage was significantly lower than in samples from the control cage and the modal length also was lower in the infested than in the control cage, though the '*t*' value of the difference in this case was slightly lower than that for the 5 per cent level of significance. The trend of the difference being in the same direction as in the case of 38F, this difference can also be considered as significant. The fibre-length irregularity percentage, the mean fibre-weight per unit length and the percentage of mature fibres were all higher in samples from the control cage than in those from the infested one, even though the differences in the averages were not statistically significant. The calculated H.S.W.C. was higher in samples from the control cage than in those from the infested one. The '*t*' value of the difference in the averages, being in this case also slightly less than that for 5 per cent level of significance, can again be treated as significant. It may, therefore, be concluded that, on the whole, a variety, susceptible to jassids, suffered a deterioration in the quality of its lint by an attack of jassids.

In both the years, 1939 and 1940, in which the highly resistant variety, P-A 289F/43, was under study, no significant difference was observed in respect of any of the six fibre characters studied in the samples of lint from the control and infested cages, excepting the percentage of mature fibres, which in 1940, was significantly higher for samples from the infested cage than for samples from the control cage. It might also be pointed out that in both the years, the mean fibre-length, modal length, mean fibre-weight per unit length and percentage of mature fibres were higher, though not significantly, in samples from the infested cage than in those from the control cage. This is contrary to what should ordinarily be expected in view of the conclusions arrived at in the previous two cases of susceptible varieties. It could be stated, therefore, that the P-A 289F/43, resistant to jassids, suffered no deterioration in its lint quality in spite of an intense infestation with jassids.

This conclusion, in respect of the jassid resistant variety, P-A 289F/43, was borne out by the study in 1940 of the fibre-characters of P-A L.S.S., a variety

also jassid resistant. The average values of mean fibre-length, modal length and calculated H.S.W.C. were not significantly different in samples from the control and infested cages. The fibre-length irregularity percentage was significantly higher in samples from the control cage and the mean fibre-weight per unit length similarly lower in samples from the control cage; the percentage of mature fibres was lower in samples from the control cage than in those from the infested cage, the 't' value for the difference in the average of this fibre-character being just short of that for the 5 per cent level of significance. The mean fibre-weight per unit length and percentage of mature fibres were, quite contrary to what should ordinarily be expected, higher in samples from the infested cage than in those from the control cage. In the case of P-A L.S.S. also as in the case of P-A 289F/43, both varieties resistant to jassids, a severe infestation with jassids produced no deterioration in lint quality.

No suitable explanation can be suggested for the very slight improvement of lint quality under severe jassid infestation in the case of both the resistant varieties (289F/43 and L.S.S.). It must, however, be made clear that no improvement in lint quality may be expected as a result of jassid attack on the resistant varieties under the general agricultural conditions.

Discussion

The present investigations on the effect of jassid attack on the development of the cotton plant and its fibre properties have revealed a very important phenomenon in that the effect of high infestation did not seem to interfere with the fibre properties and development of the plant of a resistant variety under Lyallpur conditions. In the case of a susceptible variety, on the other hand, both the development and the fibre properties were seriously interfered with by jassid infestation. Such a differential behaviour of the susceptible and resistant variety has, so far as we are aware, not hitherto been recorded. Although the growth and flowering records were taken on the susceptible and the resistant varieties in two different years, the seasonal variations alone were not probably the main factors responsible for the observed differences in the two varieties.

It must here be mentioned that the external symptoms of jassid attack—crinkling and reddening of the leaves—were quite pronounced even when the resistant varieties were under experiment. This showed that the drain on the cell sap was quite appreciable. but these varieties were able to tolerate this drain much better than the susceptible varieties.

It has always been stressed that no variety of American cotton should be released for general cultivation by the Punjab Department of Agriculture, unless its resistance to jassids has been fully tested. That this is a very sound policy is now further proved by the present investigations. The presence of jassids in quite large numbers has sometimes been observed in tracts where the resistant varieties have been sown, almost to the exclusion of any other variety and doubts have sometimes been expressed that these cottons, although resistant under normal conditions, might suffer in abnormal years when the jassids were present in large numbers. The causes which lead to the prevalence in large numbers of jassids in certain years and their virtual absence in others have not so far been elucidated, but the present investigations

have shown that the risk of deterioration, both in quality and quantity, is reduced if the cultivator resorts to sowing the resistant varieties recommended by the Punjab Department of Agriculture.

Summary

The effect of a heavy jassid infestation has been studied both on resistant and susceptible varieties of Punjab-American cottons.

It has been shown that a heavy jassid infestation has been instrumental in reducing the growth in height of the main stem, number of flowers produced, number of bolls opened and the total weight of *kapas* per plant in the case of suscepting varieties while no such ill effects were noticed in the case of a resistant variety.

In both the varieties, 38F and 289F/K.25, highly susceptible to jassids, the quality of lint suffered, in general, a deterioration by a heavy infestation of jassids. The mean fibre-length of both the varieties was lowered significantly by the infestation, while the mean fibre-weight per unit length and percentage of mature fibres also recorded a reduction, though not statistically significant.

In P-A 289F/43 and L.S.S., both varieties resistant to jassids, no significant deterioration was observed in any of the fibre-characters studied and, hence, in lint quality in general, in spite of a heavy infestation of jassids.

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STUDIES ON PRECISION OBSERVATIONS ON RICE AT KARJAT

BY

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WITH A PREFACE

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Preface

ONE of the first tasks of the Section of Agricultural Meteorology at the Meteorological Office, Poona, soon after its formation in 1932, was to examine the yield data available at the experimental farms in India and if possible to correlate them with weather factors. A preliminary examination of the data showed that in most of the experimental farms in India attention had been confined so far to manurial and varietal experiments and that even yield data falling under the category of what may be called ' farm averages ', where the yields of all varieties and treatments are lumped together and averaged, were then available only for periods up to 10 or 15 years. The only place where data relating to the same variety and similar treatment were available for a comparatively long series of years was the Cawnpore Experimental Farm where experiments on wheat [Kalamkar and Singh, 1935] had been in progress continuously during the period 1885—1913.

About this time the Agricultural Meteorology Committee in Great Britain under the leadership of Prof. R. A. Fisher had conceived the idea of collecting what has been called ' precision observations ' on wheat by applying the new methods of random sampling. The observations aim at tracing the entire life-history of the crop from the date of sowing to the date of harvest together with the variations in the climatic environment of the crop during the season at a selected number of centres for a series of years. An account of this work wi'l be found in [Russell and Watson, 1940] Technical Communication No. 40 of the Imperial Bureau of Soil Sciences.

In India we decided to develop the sampling technique suitable for some of the important crops on the lines of the British scheme. Short crops like wheat and rice were experimented with during the last few years while work on the taller crops like *jowar* and sugarcane has been started a couple of years ago. In work of this nature an initial period of experimentation and trial is absolutely essential for deciding upon a final and satisfactory procedure for estimating the growth and yield of different crops. It may be said that so far as short crops like wheat and rice are concerned the ' initial ' period is almost over ; with regard to the tall crops we are still passing through that period. During the next few years when the preliminary work is completed we shall be in a position to fix the most suitable sampling technique for different crops.

This work has now assumed a certain amount of urgency and importance in view of the fact that agricultural institutions and workers in India are realizing that the old methods of crop estimation will have to give way before the modern objective methods. At a recent meeting (February 1942) of the Board of Agriculture and Animal Husbandry in India one of the important subjects discussed was the need for starting of weather and crop observations on a systematic basis at a number of centres representative of the important crops of the country. We are thus faced with the problem of laying the foundations in India of sound crop and weather statistics.

The present paper deals with the precision observations on rice recorded at Karjat during the last few years according to a scheme prepared by the Agricultural Meteorology Section at Poona. Dr B. S. Kadam, the Crop Botanist to the Government of Bombay, was very enthusiastic in arranging for these observations at Karjat and his cooperation has been invaluable. Dr R. J. Kalamkar was responsible for the scrutiny of the data and the guidance of the computors up to 1937 ; later this side of the work was continued by Messrs. V. Satakopan and S. Gopal Rao. The introduction dealing with the general geographical and agricultural features of the Karjat area has been contributed by Dr Kadam. The investigation is an example of healthy cooperation between the Crop Botanist to the Government of Bombay (Dr Kadam) and the workers on agricultural meteorology at Poona. *The paper is the result of team work in which all the authors have contributed more or less equally.*

In concluding this preface I must record my grateful thanks to the Director of Agriculture, Bombay Province, for the cooperation extended through Dr Kadam and to Dr C. W. B. Normand, Director General of Observatories, for his keen interest in the progress of these pioneer investigations.

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Introduction

RICE is the third important staple crop in the Bombay presidency. Its cultivation extends from one end of the province to the other and is confined mostly to the coastal areas. Compared to the major rice-producing provinces, the acreage in the Bombay presidency is very small, being only 20,00,000 acres. This area produces roughly 8,00,000 tons of rice, an amount which is insufficient to meet the entire demand of local consumption. Bombay is therefore a deficit province, and has been depending mostly on Madras and Burma to supplement the local production of rice.

Although the aggregate acreage under rice in the province is small, it is distributed over a length of 640 miles, thus presenting extraordinary variations of soil, climate, varieties and agricultural practices. The whole area, therefore, groups itself into distinct zones. These are (1) Gujarat, (2) North Konkan, (3) South Konkan, (4) Maval, (5) Malnad, and (6) Kanara. In view of the variety of conditions in which the rice crop has to grow the Department of Agriculture in Bombay has devoted considerable attention to the genetic improvement of this crop. At present there is a string of five rice-breeding stations throughout the length of the province and it is contemplated to add three more stations in the near future.

The most important rice-growing zone, from the point of acreage and export of local rices, is north Konkan. It comprises the districts of Thana and Kolaba and Bombay suburban districts. The first rice-breeding station was opened at Karjat in the Kolaba district in the year 1919. This station has developed a large number of improved strains from the famous Kolamba rice. These are now spreading very extensively in the north-Konkan zone. The Rice Breeding Station at Karjat is the premier station in the province and has devoted also considerable attention to ancillary problems concerning rice cultivation. Our studies were conducted at this station. In order that the reader may gain a proper perspective of the general rice cultivation in this part of the province of Bombay, a brief description of the environment and cultural methods of rice cultivation is presented here.

Climate and rainfall. There are four distinct seasons. The cold season is from November to March. During this period the temperature at Karjat during the day varies from 61° F. in the morning to 95° F. in the afternoon. The cold spell is followed by the hot weather, lasting from April to June. During these months the temperature often touches the 116°F. mark. The heat is very oppressive. The month of April is the hottest.

The onset of the monsoon in June brings the long awaited relief from the summer heat. The rainy season lasts up to the end of September, and in some years extends into the month of October. During this month the weather is damp and very hot.

The rainfall in the district varies from 90 to 150 in., heavier rainfalls being confined to the foot of the hills of the Western Ghats. The months of July and August are the wettest receiving over 64 per cent of the total rainfall. The average rainfall for the period 1931-40 is 138 in. at Karjat. The distribution of rainfall is very important during the growing period of the paddy crop.

Soils. The rice soils in the north Konkan are derived from trap and are mainly of two kinds. The high-lying shallow and reddish types of soils support earlier ripening varieties of rice, and when the soils are very poor they give way to lesser millets such as *vari* or *nachani*.

The heavier rice soils are situated at a lower level, usually in the valleys or the plains. These soils are blackish or dark brown in colour. Being more retentive of moisture they are suitable for mid-late and late varieties of rice. The upper layers of these soils receive washings from the hills or uplands. In depth, therefore, the soils vary from 6 to 18 inches. The upper layer is overlaid on *murum* or disintegrated rock ; hence the drainage is very good.

Soils in north Konkan are generally considered deficient in nitrogen, but have sufficient supplies of potash, phosphoric acid and other minerals to support normal growth of rice.

Methods of cultivation of rice. Throughout north Konkan, rice is grown as a cultivated and as a transplanted crop except when grown on salt lands and in summer. Seedlings required for transplanting are raised in nurseries with specially prepared seed beds. Throughout the off season the farmers prepare these beds which are carefully covered with layers of dry cowdung pieces and litter of dry leaves and branches and dry grass. The whole is fired some time before the month of June, leaving a friable seed bed. After this, the cultivator waits for the first showers of rain. With the setting in of the monsoon, in the beginning of June, rice seed is broadcasted and mixed in with the soil by light

ploughing. Sometimes the farmers sow seed in dry seed-beds before any rains are received.

Under normal conditions, seedlings are ready for transplanting in three to four weeks. The seedlings are transplanted in bunches of 10 to 15 seedlings in well-puddled fields. The bunches are set at random, but the distance usually varies from 9 to 12 in. and even up to 18 in. in very heavy soils. It takes about a fortnight for the new crop to set in. After this period weeding is usually done.

The early crops commence to flower during the month of September, while the late ones do so in the beginning of October. Flowering is a critical period in the life of the plants and if it rains heavily at this time the filling of the grains is affected. The grain matures in three to four weeks, the earlier varieties requiring a little longer time than the late ones, as later in the season the temperature being higher the crop ripens faster.

The early varieties ripen in October and the late varieties in November. The crop is harvested by hand and laid up in sheaves. It is allowed to remain in the fields for about two days and then gathered up in bundles. The bundles are carried to the threshing yard and stocked with ears towards the centre of the stack. The top of the stack is covered up with straw or some other material in such a way that rain water runs off easily. The stacks are built on a wooden or earthen platform.

The crop is threshed in small bundles by striking against a wooden bench. Rice grain separates easily and a few strokes suffice to loosen all the grain from the bundle. If the variety is hard to thresh, the grain is separated by treading under bullock's feet. The grain is dried well for storing.

The yield of rice varies considerably from tract to tract since soil and season, variety and intensity of cultivation play an important part in determining the yield. Early varieties usually give an outturn ranging from 1000 to 1800 lb. while late varieties usually yield 2000 to 3200 lb. per acre.

Precision observations on rice

Sampling technique 1934

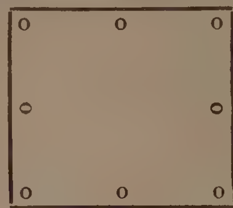
For the purpose of observing the developmental characters of the crop by sampling, a plot of land at the Rice Breeding Station at Karjat 70 ft. × 50 ft. was marked out in 1934 and divided into five blocks. Each block was divided into two plots and each plot was further divided into two sub-plots of 7 ft. × 25 ft. each. One plot in each block was transplanted with regular lines with eight seedlings per bunch, the distance between the bunches being 1 foot. The other plot in the block was transplanted according to the cultivator's method where the number of seedlings per bunch and also the spacing of the bunches varied. The observations were taken in both plots this year.

Sampling for regular planting. Each sub-plot with regular planting had seven rows of 25 bunches each, giving 175 bunches in all. Out of the seven rows three were chosen at random and from each row a sampling unit of eight bunches was selected. The sampling unit consisted of four pairs of adjacent bunches separated by three bunches in between as indicated below—

$$\mathrm{O\ O}\underbrace{\mathrm{X\ X\ X}}_{\text{Omit}}\mathrm{O\ O}\underbrace{\mathrm{X\ X\ X}}_{\text{Omit}}\mathrm{O\ O}\underbrace{\mathrm{X\ X\ X}}_{\text{Omit}}\mathrm{O\ O}$$

The observations were made on these eight bunches.

Sampling for irregular planting. In the case of irregular planting a frame three feet square was used and eight bunches nearest to the four corners and the four mid-points of the sides of the frame formed a sampling unit as indicated below. The location of the frame inside the plot was fixed by randomization. Three such samples were taken from each half-plot.



Twenty-four bunches were thus sampled from each sub-plot in both types of planting for this year.

Sampling technique 1935-40

In the six years 1935 to 1940 the precision observations were taken in the 'season plot' on the farm. A block of 84 ft. × 25 ft. was marked out in this and divided into 12 plots of 7 ft. × 25 ft. Each plot had seven rows of 25 bunches of regular transplanted rice, there being 10 seedlings per bunch. Out of the seven rows in each plot four were chosen at random and a sampling unit of eight bunches from each row was selected as indicated in the technique for regular planting plots in 1934. In all 32 bunches were observed from each plot every time.

Characters observed

Observations were started a fortnight after the transplanting every year and were repeated at weekly intervals, fresh random selection of the sampling units being made on each occasion. For each chosen bunch three characters were observed, namely, the number of culms, the height and the number of leaves. The main plants could not be distinguished from their tillers and so the total number of culms only were noted. The height upto the base of the fully expanded topmost leaf of the plant nearest to the observer in each bunch was recorded.

At the time of the harvest, the bunches on which measurements were taken on the last date were separately cut and threshed and the weights of paddy and straw from each separately recorded. The length of the panicle of the plant whose height was measured was also recorded. The remainder of the plot, after cutting the 32 bunches, was harvested and the yields of paddy and straw so obtained were determined. Table I gives further details regarding the experiment from year to year. The fortnightly rainfall at the station for the period of the experiment is given in Table II.

Results of 1934 observations

As already mentioned, in the year 1934 observations were taken on the 'regular' and 'irregular' sown plots. It will be seen from Table I that the scheme of the experiment was quite uniform during the years 1935 to 1940. In the first year (1934), however, the number of plots, number of samples, etc.

were different and so the data for this year have been discussed separately here. The observations of the six years 1935--1940 have been considered together later.

The layout of the experiment was of the randomized block type with five replications in 1934. Three sampling units of eight bunches each were observed from each of the two sub-plots into which a plot was divided. The allocation of the degrees of freedom for the 480 observations of each character for any one occasion was as follows :

Due to	D. F.
Blocks	4
Treatment*	1
Experimental error	4
Sub-plots	10
Sampling error	40
Within samples	420
Total	479

Of the three characters observed on each occasion, the number of leave. did not show much variation and therefore its variance was not analyseds Tables III(A) and III(B) show the analysed variances for (1) number of culms and (2) height for each day of observation together with the analysis of variance of panicle length, paddy and straw yields at harvest.

The following comparisons have been made and the significant differences in the variances have been indicated in the tables.

(*a*) *Block and treatment variances.* The block and treatment variances have been compared with the experimental error variances. The block variance is not significant showing that the blocks are not any more different from one another than the plots themselves. It is found that, in spite of the small number of degrees of freedom available for estimating the experimental error, only four, the treatment variances are significant in many cases. For the number of culms the treatment variance is highly significant for all the weeks while for height it is significant only for eight weeks. The treatment variance is not significant for panicle length and paddy yield but is significant for straw yield. The significant differences noted above indicate differences in the nature of the crop for the two methods of planting and will be referred to again later in the paper while discussing the mean value of the characters.

(*b*) *Sub-plot variances.* It is desirable, when sampling is resorted to, to sub-divide the units from which samples are taken into one or more parts and take equal number of samples from each sub-unit instead of random samples from the whole, to ensure representative sampling. Sampling will be more efficient, if controlled as above, especially in a population where the unit from which samples are taken exhibits systematic differences within itself. Such differences, if any, will be shown by higher variance between sub-units themselves. In the present experiment it was found that the sub-plot variance is generally less than the 'experimental error' variance except in a few cases. For three weeks in the case of height and for straw yield at harvest, the sub-plot variance is significantly higher. It will be shown later that even this difference is manifest only in the case of irregular planting.

* Methods of planting, i.e. regular and irregular

TABLE I

Statement showing the details of precision observations on rice at Karjat during the years 1934—40

	1934		1935	1936	1937	1938	1939	1940
	Regular	Irregular						
1. Size of the plot (in ft.)	7 × 50	7 × 50	7 × 25	7 × 25	7 × 25	7 × 25	7 × 25	7 × 25
2. Number of plots	5	5	12	12	12	12	12	12
3. Date of sowing nursery	11-6-34	11-6-34	8-6-35	4-6-36	14-6-37	5-6-38	9-6-39	8-6-40
4. Date of transplanting	11-7-34	11-7-34	5-7-35	4-7-36	12-7-37	4-7-38	5-7-39	9-7-40
5. Date of first observation	25-7-34	25-7-34	19-7-35	18-7-36	26-7-37	27-7-38	2-8-39	23-7-40
6. Variety of rice	K 226	K 226	K 42	K 42	K 42	K 42	K 42	K 42
7. Spacing of bunches (in inches)	12 × 12	Irregular	12 × 12	12 × 12	12 × 12	12 × 12	12 × 12	12 × 12
8. No. of seedlings planted per bunch	8	Irregular	10	10	10	10	10	10
9. Sampling method	3 random rows in each sub-plot were chosen and 8 bunches in a dissected manner were observed from each row	3 random locations were made in each sub-plot and with a square frame 8 bunches were observed	4 rows were chosen at random from each plot and 8 bunches in a dissected manner were observed from each row					
10. Date of harvesting	1-11-34	1-11-34	31-10-35	27-10-36	1-11-37	3-11-38	31-10-39	7-11-40
11. Total No. of bunches in each plot	350	...	175	175	175	175	175	175
12. No. of bunches observed each time	48	48	32	32	32	32	32	32
13. Percentage sampled	13·7	Indeterminate	18·3	18·3	18·3	18·3	18·3	18·3

TABLE II

Distribution of fortnightly rainfall during the years 1934—1940 at the Rice Breeding Station, Karjat

Year	May		June		July		August		September		October		November		December		Total
	1—15	16—31	1—15	16—30	1—15	16—31	1—15	16—31	1—15	16—30	1—15	16—31	1—15	16—30	1—15	16—31	
1934	...	...	3·97	29·32	21·03	15·31	23·10	13·30	6·80	3·46	1·75	0·10	2·35	...	...	...	120·49
1935	...	...	1·94	23·85	16·34	34·40	5·86	19·21	11·57	3·14	...	3·65	0·05	...	...	...	120·01
1936	...	...	4·42	32·90	13·42	19·72	16·97	12·73	17·74	2·86	0·01	...	1·69	0·38	...	...	122·84
1937	...	...	0·60	24·87	29·84	41·92	10·33	6·05	14·40	12·76	2·34	0·13	0·06	...	...	...	143·30
1938	...	0·87	20·44	25·97	23·85	32·82	9·92	23·27	5·87	4·83	21·41	...	0·21	...	...	...	169·46
1939	...	...	5·97	7·65	35·54	7·85	4·25	39·72	7·60	1·33	0·61	1·21	0·24	...	...	...	111·97
1940	...	...	2·69	26·12	17·16	44·27	21·26	21·71	4·72	19·28	1·67	5·13	...	0·29	...	...	164·30

TABLE III (A)

Analysis of variance of number of culms for each week and harvest characters for 1934

Factor	D. F.	Number of culms per bunch														Harvest character		
		Number of the week														Panicle length in cm.	Straw yield in gm.	Paddy yield in gm.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14			
Blocks	4	44·0	46·7	77·7	45·9	52·4	18·1	12·9	37·7	9·4	19·9	10·7	10·9	11·5	11·6	15·9	19·7	131·6
Treatment	1	4183·1‡	3167·3‡	3996·3‡	3713·0‡	1884·2‡	2336·4‡	1533·7‡	3582·1‡	2079·2‡	1555·2‡	1530·1‡	1569·6‡	2622·7‡	1687·5‡	468·2	492·1‡	15·7
Experimental error	4	38·8	53·5	16·6	33·6	35·2	48·5	13·0	36·3	38·9	11·5	9·5	27·4	20·2	30·3	122·2	19·6	54·4
Sub-plots	10	13·9	27·9	31·5	31·1	14·8	26·3	14·0	12·0	10·3	17·1	9·0	18·0	19·5	19·3	2·8	151·5†	134·5
Sampling	40	16·3‡	11·9‡	13·9‡	9·7	17·8‡	6·8	14·4‡	8·0†	12·0	8·7	17·7‡	10·9‡	18·0‡	12·6‡	4·4†	26·1	58·6†
Within samples	420	6·8	5·9	7·8	7·7	6·6	6·5	6·8	5·5	9·1	7·0	6·3	6·2	7·0	6·1	2·8	26·7	33·6

TABLE III (B)

Analysis of variance of height (in cms.) observations for each week in 1934

Blocks	4	41·3	12·0	7·4	23·5	46·0	12·9	55·3	45·4	198·8	67·2	483·7	703·4	549·1	776·8‡	...	...	...
Treatment	1	56·7	129·2†	401·5‡	95·4	262·6†	48·1†	0·3	298·4‡	6·8	221·4	3146·8	578·6	21362·4	2325·4‡	...	...	...
Experimental error	4	54·0	13·6	12·8	19·0	27·6	4·4	31·4	14·0	33·7	32·7	508·6	632·6	175·1	19·3	...	...	...
Sub-plots	10	11·6	11·1	3·8	9·7	3·1	46·7†	28·2	134·8†	55·7	127·4	328·3	258·9	124·5	478·3‡	...	...	...
Sampling	40	9·9‡	4·6	5·1	4·4	5·1	10·1†	10·8	5·7	28·7†	55·3‡	148·5‡	352·7‡	119·1‡	119·6‡	...	...	...
Within samples	420	5·1	4·0	3·7	5·5	6·9	6·8	11·2	14·6	17·9	32·5	59·7	60·1	62·0	50·4	...	...	...

† Significant at 5 per cent level ‡ Significant at 1 per cent level

(c) *Sampling variance.* The sampling variance is seen to be generally higher than the 'within samples' variance and significantly so in many cases. This indicates the existence of a positive correlation between the ultimate units, i.e. the bunches in the same sample.

The comparisons made above are based upon the variances estimated from the samples taken from both the methods of planting. It is, however, recognized that differences in sampling errors may arise due to variation in the structure of the sampling unit [Kalamkar, 1932] and in the present case due to differences in the methods of planting. In view of this fact analyses of variance have been carried out separately for the two methods of sampling for all the above observations and are shown in Tables IV (A) and IV (B).

A comparison of the sub-plot variance with plot variance in these tables indicates that generally they are not significantly different though for a few cases in 'irregular planting' the differences are significant. It thus appears that there is no advantage in dividing the plots of the size used in the experiment into smaller units for the purposes of sampling especially in dealing with the crop planted regularly.

The 'sampling' and 'within samples' variances, in Tables IV (A) and IV (B) when compared indicate that the positive correlation between the bunches within the same sample is not peculiar to one method of planting alone, for significant differences occur for both methods. While the presence of this correlation in the linear sampling unit of the regular planting may lead one to suspect that the adjacent bunches chosen therein might have been the cause, the presence of a similar correlation in the irregular crop from which the bunches have been chosen along the sides of a square yard indicates that the correlation may exist not only among bunches quite near each other but also among bunches in the same locality. Considering, however, the normal spacing in an irregular crop it is quite possible also that a few of the bunches in each sample from the irregular crop were located adjacently and so it is not possible to say whether this correlation is a feature of adjacent bunches alone or amongst bunches in the same locality without further studies. It appears, however, that both the sampling structures, i.e. the linear one for the regular crop and the square-yard one for the irregular crop require modification in the light of the above results.

Table V shows the experimental and sampling errors derived from Tables IV(A) and IV(B) as percentages of mean values of the characters concerned for each week's observations and harvest characters. Comparing these errors for the two methods of planting it is seen that the method of planting does not show any consistent difference on the experimental or sampling errors. While in certain cases the errors are higher for the irregular planting, there are instances where the reverse is also true though on an average the errors for the irregular planting are slightly higher than those for the regular planting.

The mean values of number of culms per bunch, the height and the number of leaves for each week of observation together with the mean values of the harvest characters are shown in Table VI. The experimental and sampling errors for the means are also shown for each week and for the harvest characters except for the number of leaves. Fig. 1 shows graphically the mean heights and the mean values of the number of culms.

FIG. 1.

The number of culms per bunch for the cultivator's method has been significantly higher than in the case of regular planting. In the irregular planting there are on an average 4 to 5 culms per bunch more than in the regular planting. At harvest the numbers of culms per bunch are 10·7 and 14·4 for regular and irregular planting respectively.

The heights of the plants in the two methods of planting do not show much difference during the early stages of the crop but during subsequent stages however the plants in the regular method show greater height.

It is curious to note that the average height of the plants taken at the time of harvest in the regular planting shows a significantly lower value than the average height observed a fortnight before, due to defective sampling. In general, however, no such significant discrepancies were noticed in respect of the attributes measured.

The final height of the plant and the panicle length for the irregular method show significantly lower values, while the number of culms and the yield of straw per bunch show higher values than for the regular planting. There was, however, no significant difference in the yield of paddy for the two methods; the shorter panicle length probably acted as a set off against the greater number of culms per bunch. However, the greater number of culms per bunch has reflected in the higher straw yield for the cultivator's method.

TABLE IV(A)

Separate analysis of variance for 'regular' and 'irregular' crops for 1934 : Number of culms per bunch for each week and harvest characters

Factor	D. F.	Number of culms per bunch: No. of the week 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Harvest characters: Panicle length in cm.	Straw yield in gm.	Paddy yield in gm.
(i) Regular																		
Plots	4	4·9	5·2	32·0	14·6	57·5	25·4	3·2	24·2	14·3	14·9	2·4	29·1	10·9	5·4	3·3	17·1	162·6
Sub-plots	5	9·0	5·7	20·4	2·6	2·6	13·1	8·9	5·9	2·4	3·2	9·3	14·5	1·4	13·4	4·3	101·0	93·9
Sampling	20	5·2‡	3·2	11·7‡	7·7	5·0	4·4	7·2	5·0	8·4‡	4·6	9·5‡	4·2	8·0‡	5·5†	4·0‡	32·3	48·3
Within samples	210	1·8	2·3	4·6	5·9	4·7	4·4	5·3	3·7	4·2	3·8	3·2	3·8	3·1	3·1	2·1	21·3	31·0
(ii) Irregular																		
Plots	4	77·9	95·0	62·3	65·0	30·2	41·2	22·7	49·8	34·0	16·5	17·8	9·3	20·7	36·5	17·8	22·2	23·4
Sub-plots	5	18·9	50·0	42·6	59·5	27·0	39·5	19·2	18·0	18·1	31·0	8·7	21·4	37·7	25·2	1·4	202·1†	175·2†
Sampling	20	27·5‡	20·7‡	16·7	11·7	30·6‡	9·2	21·7‡	11·0	15·6	12·9	25·9‡	17·4‡	27·9‡	19·7‡	4·9	19·9	68·9†
Within samples	210	11·7	9·5	11·1	9·5	8·6	8·6	8·4	7·5	13·9	10·2	9·4	8·5	10·9	9·2	3·5	32·1	41·9

† Significant at 5 per cent level ‡ Significant at 1 per cent level

TABLE IV(B)

Separate analysis of variance for 'regular' and 'irregular' crops for 1934 : Height in cm. for each week of observation

Factor	D. F.	Number of culms per bunch													
		No. of the week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
(i) Regular															
Flot . . .	4	12·3	1·7	10·1	27·9	41·4	7·4	48·0	45·9	145·8	89·8	249·7	224·5	644·6	367·4
Sub-plots . . .	5	10·0	7·6	3·7	11·1	4·1	33·4	24·7	31·4	64·7	74·5	335·8	236·2	69·8	148·8
Sampling . . .	20	12·9‡	3·0	6·2†	4·8	3·4	13·1‡	10·9	19·0	22·4	52·2‡	98·8‡	86·0	144·8‡	57·2
Within samples . .	210	6·4	4·1	3·9	5·7	6·7	6·6	13·0	12·8	16·9	26·4	49·0	82·7	51·8	41·9
(ii) Irregular															
Flot . . .	4	83·0	23·9	10·2	14·6	32·2	9·9	38·8	13·4	86·4	10·0	742·5	1111·5	79·6	431·5
Sub-plots . . .	5	13·3	14·6	3·9	8·3	2·2	60·1†	31·8	38·1	46·6	180·4‡	320·8	281·7	179·2	309·7
Sampling . . .	20	6·9†	6·2	4·0	4·1	6·9	7·2	10·7	42·4‡	34·7†	58·5	198·2‡	619·4‡	93·5	181·9‡
Within samples . .	210	3·9	3·9	3·6	5·2	7·1	6·9	9·5	16·6	18·2	38·6	70·5	37·4	72·2	59·0

† Significant at 5 per cent level

‡ Significant at 1 per cent level

TABLE V

Percentage experimental and sampling errors for 'regular' and 'irregular' crops for each week and harvest characters

Week No.	Culms per bunch				Height in cm.			
	Percentage error per bunch separate for the two methods of planting				Percentage error per bunch separate for the two methods of planting			
	Regular		Irregular		Regular		Irregular	
	Experimental error	Sampling error	Experimental error	Sampling error	Experimental error	Sampling error	Experimental error	Sampling error
1	30·3	31·0	..	..	31·3	32·0	86·3	24·9
2	27·1	21·3	77·4	33·4	11·9	15·6	40·4	20·6
3	54·5	32·9	48·8	25·2	26·8	21·1	23·3	14·5
4	34·4	24·9	48·4	20·6	34·0	14·1	26·0	13·8
5	62·5	18·4	34·1	34·3	41·1	11·7	33·1	15·3
6	46·3	19·3	41·9	19·8	14·3	19·0	17·1	14·5
7	15·1	22·6	30·8	30·1	33·6	16·0	30·3	15·9
8	44·3	20·1	42·5	20·0	26·1	18·2	15·0	26·5
9	32·3	24·9	36·8	24·9	42·9	16·8	33·3	21·1
10	33·9	18·8	27·1	23·9	26·6	20·3	9·2	22·3
11	14·0	27·8	28·7	34·6	25·8	16·3	48·6	25·1
12	48·2	18·2	20·6	28·2	17·4	10·7	39·7	29·6
13	30·6	26·2	29·3	34·1	26·5	12·7	10·7	11·6
14	21·8	21·9	41·9	30·8	21·0	8·3	23·9	15·5

Harvest characters

	Regular: Experimental error	Regular: Sampling error	Irregular: Experimental error	Irregular: Sampling error
Panicle length in cm. .	8·6	9·4	21·9	11·5
Straw yield in gm. .	57·8	32·8	22·5	38·5
Paddy yield in gm. .	18·4	25·3	19·2	18·2

TABLE VI

Mean values with their experimental and sampling errors for number of culms, etc. for each week and harvest characters 1934

Week No.	Number of culms				Height in cm.				Mean number of leaves	
	Mean		Experimental error for the mean	Sampling error for the mean	Mean		Experimental error for the mean	Sampling error for the mean		
	Regular	Irregular			Regular	Irregular			Regular	Irregular
1	7·3	13·2	·428	·261	11·2	10·5	·415	·020	3·5	2·9
2	8·5	13·6	·441	·223	11·1	12·1	·225	·138	4·0	3·6
3	10·4	16·2	·569	·241	11·8	13·7	·174	·145	4·0	3·8
4	11·1	16·7	·438	·201	15·6	14·7	·313	·136	4·1	4·2
5	12·1	16·1	·467	·272	15·6	17·1	·438	·146	4·6	4·1
6	10·9	15·3	·275	·168	19·0	18·4	·232	·205	4·1	4·3
7	11·9	15·5	·232	·245	20·6	20·6	·480	·212	4·9	4·2
8	11·1	16·6	·396	·182	26·1	24·5	·435	·015	4·3	4·2
9	11·7	15·8	·198	·224	28·1	27·9	·910	·346	4·6	4·6
10	11·4	15·0	·288	·191	35·7	34·3	·529	·480	4·8	4·8
11	11·1	14·7	·211	·272	61·1	56·0	1·420	·787	5·1	5·2
12	11·2	14·8	·214	·213	86·2	84·0	1·712	1·212	4·1	3·4
13	10·8	15·5	·218	·274	95·8	83·6	1·513	·705	3·1	2·7
14	10·7	14·4	·220	·229	91·4	87·0	1·799	·706	3·7	3·6

Harvest characters

	Regular	Irregular	Experimental error for the mean	Sampling error for the mean
Panicle length in cm. . . .	21·20	19·23	·258	·135
Straw yield in gm. . . .	22·48	24·50	·091	·104
Paddy yield in gm. . . .	21·20	21·56	·219	·179

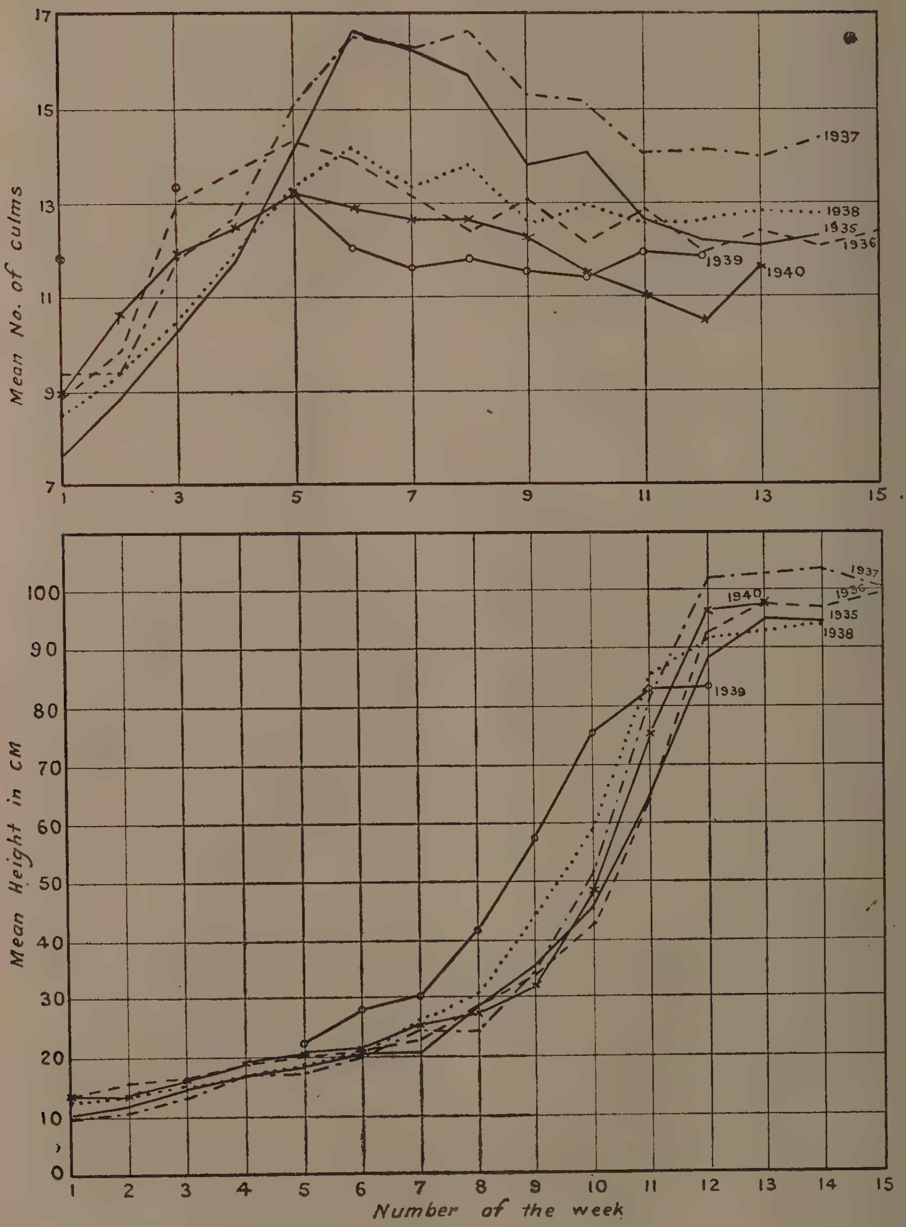
Results of observations 1935—1940

The results of 1934 observations have been discussed in some detail above as observations were taken in 'regular' and 'irregular' sown plots. For the years 1935—1940 the observations have been carried out in the case of one method of planting only (i.e. regular) in 12 plots. Further details of the nature of the experiment have already been shown in Table I. The characters observed were the same as in 1934, namely, the number of culms in each bunch, the height of bunch and the number of leaves per bunch for each time of observation together with the panicle length and the yields of straw and paddy at harvest. In these years four sampling units were taken from each plot without subdivision. The analysis of variance for the 384 observations taken for each character at a time will thus have the following allocation of degrees of freedom :

Due to	D. F.	Variance
Plots	11	A
Sampling error	36	B
Within samples	336	C
Total	383	

The analysis of variance has been carried out for all the characters observed except for leaves where no appreciable variability was noticed. Tables VII(A) and VII(B) give in a tabular form the mean values of the number of culms per bunch and the mean height in cm. for the various weekly observations together with their percentage sampling errors per bunch. At the bottom of Table VII(B) are also given the mean values of other characters observed at harvest, namely, the panicle length, the paddy and straw yields per bunch for the respective years. The mean number of leaves are also shown in Table VII(C). The mean values of number of culms and the height for various years are shown graphically in Fig. 2 which brings out the differential response of the characters to seasons. It may be interesting to note that the year 1937 seems to have been the most favourable season for the crop. In this year, the number of culms, the height at harvest and the yield of paddy were the highest among the 6 years under consideration.

Growth features of the crop. The crop gets ready for harvest within 15 to 16 weeks after its transplantation. Observations on crop growth were started after a fortnight of its transplantation. From a study of Fig. 2 it will be observed that, in general, the number of culms increases and attains a maximum by the sixth or seventh week after transplantation, remains more or less constant for about a fortnight and then decreases due to the fact that some of the late formed tillers do not survive. This decrease is to be noticed for about three weeks by which time the crop is 13 weeks old from transplantation and thereafter the average number of culms remains constant till the harvest. It will be seen from the figure that the maximum for the number of culms reached was more for the seasons 1935 and 1937 but the survival was greatest for 1937 only. In other years the average number of culms at harvest was more or less the same.



Mean No. of culms
17
15
13
11
9
7
1
3
5
7
9
11
13
15
1937
1938
1935
1936
1939
1940
Mean Height in CM
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1937
1936
1940
1935
1938
1939
Number of the week

FIG. 2.

TABLE VII(A)

Mean values of number of culms per bunch for each week together with the percentage sampling errors, 1935—40

Week No.	1935 Mean	1935 Sampling error per cent per bunch	1936 Mean	1936 Sampling error per cent per bunch	1937 Mean	1937 Sampling error per cent per bunch	1938 Mean	1938 Sampling error per cent per bunch	1939 Mean	1939 Sampling error per cent per bunch	1940 Mean	1940 Sampling error per cent per bunch
Starting date of observations	19-7-35		18-7-36		26-7-37		27-7-38		2-8-39		23-7-40	
1	7·7	17	8·8	34	9·3	15	8·5	..	11·8	19	9·0	20
2	8·8	23	9·8	21	9·3	15	9·4	..	..	..	10·7	22
3	10·3	23	13·0	21	11·8	24	10·6	28	13·4	15	12·0	18
4	11·8	17	11·8	18	12·7	22	12·0	25	..	..	12·5	18
5	14·2	43	14·3	21	15·0	21	13·4	19	13·4	21	13·2	19
6	16·7	19	13·9	24	16·6	17	14·2	16	12·1	13	12·9	14
7	16·3	15	13·2	19	16·3	16	13·4	20	11·7	17	12·7	19
8	15·7	14	12·4	18	16·6	19	13·9	20	11·8	19	12·7	17
9	13·8	15	13·1	16	15·3	16	12·7	19	11·5	15	12·3	15
10	14·1	14	12·1	18	15·2	16	13·0	19	11·4	16	11·6	16
11	12·7	16	12·8	18	14·1	19	12·6	19	11·9	16	11·1	16
12	12·2	13	11·9	21	14·2	15	12·7	16	11·8	13	10·6	18
13	12·1	18	12·4	14	14·2	15	12·8	21	..	..	11·7	14
14	12·3	14	12·1	14	14·0	21	12·8	18	..	..	..	..
15	..	..	12·3	14	14·4	17	..	..	..	..	..	..
16	..	..	..	..	..	..	..	..	..	..	11·1	18

TABLE VII (B)

Mean values of height for each week and of harvest characters together with their percentage sampling errors, 1935—40

Week No.	1935 Mean (cm.)	1935 Sampling error per cent per bunch	1936 Mean (cm.)	1936 Sampling error per cent per bunch	1937 Mean (cm.)	1937 Sampling error per cent per bunch	1938 Mean (cm.)	1938 Sampling error per cent per bunch	1939 Mean (cm.)	1939 Sampling error per cent per bunch	1940 Mean (cm.)	1940 Sampling error per cent per bunch
Starting date of observations	19-7-35		18·7-36		26-7-37		27-7-38		2-8-39		23-7-40	
1	10·1	20	13·6	19	9·6	22	12·9	..	14·1	17	11·1	15
2	12·0	17	15·4	16	11·7	20	13·2	..	..	..	13·3	19
3	15·5	13	16·2	11	13·5	18	13·8	17	17·8	13	16·1	17
4	16·5	10	18·6	13	17·0	11	17·1	11	..	..	19·1	13
5	18·4	18	19·8	15	17·9	10	19·6	13	22·3	10	20·4	9
6	20·7	9	21·1	12	20·4	10	21·4	18	28·0	11	21·8	12
7	21·0	8	23·3	17	25·1	12	26·7	13	29·9	10	24·9	15
8	29·2	13	28·2	12	24·4	20	31·5	15	41·8	10	27·9	10
9	35·7	12	33·7	16	34·2	14	44·3	16	57·9	14	32·6	19
10	45·8	12	42·5	11	51·1	15	59·7	15	75·4	8	48·3	12
11	65·5	9	62·9	12	80·1	10	85·4	8	83·1	8	75·4	9
12	88·6	8	92·6	9	101·5	8	91·8	6	83·2	8	96·1	6
13	95·2	7	97·8	8	102·7	9	92·2	8	..	..	97·7	6
14	94·7	7	97·1	9	103·6	8	93·8	7	..	..	..	..
15	..	..	98·8	9	100·6	10	..	..	..	..	..	..
16	..	..	..	..	..	..	..	..	..	..	100·0	8
Panicle length at harvest in cm.	..	..	23·9	11	21·8	11	22·5	8	21·0	9	23·3	7
Mean yield of straw in gm. per bunch	38·1	18	30·9	22	33·0	24	27·8	23	25·5	16	25·5	22
Mean yield of paddy in gm. per bunch	23·9	15	26·7	21	31·5	22	26·8	25	24·5	18	22·7	30

TABLE VII(C)

Mean number of leaves per plant for each week's observation for the years 1935—40

Week No.	1935	1936	1937	1938	1939	1940
1 .	3·4	3·3	3·1	4·7	4·2	3·0
2 .	4·1	3·9	3·4	4·6	..	4·0
3 .	4·1	4·0	3·7	4·6	4·5	4·8
4 .	4·3	4·4	4·0	4·6	..	5·0
5 .	4·6	4·4	4·3	4·4	4·9	5·1
6 .	4·4	4·7	4·4	4·6	4·5	5·0
7 .	4·6	4·7	4·6	4·8	4·8	5·0
8 .	5·1	4·9	4·4	5·0	5·0	5·0
9 .	5·3	5·0	5·2	4·7	5·1	5·0
10 .	5·3	5·1	5·1	3·6	4·1	5·1
11 .	5·1	4·6	4·7	3·0	3·7	5·0
12 .	4·3	5·1	3·4	1·9	2·8	4·0
13 .	3·4	4·2	..	..	..	3·0
14 .	2·5	2·8	..	..	..	..
15 .	..	1·6	..	..	..	..
16 .	..	..	..	..	..	..

The period of quickest growth of the crop as indicated by its average height taken up to the base of the topmost fully expanded leaf appears to be during the 8th to 13th week from transplantation. The height attains its maximum by the 13th week and remains constant thereafter. The average height attained was greatest for the year 1937.

Suitability of the sampling structure. While discussing the results of 1934 observations, it was found that the 'sampling variance' was generally higher than the 'within samples' variance, indicating a positive correlation between the bunches in the same sample. For the years 1935—40 Tables VIII(A) and VIII(B) give the values of the above two variances for a similar comparison.

It will be seen that the variance due to 'within samples' is generally smaller than that due to 'sampling' in these years also, but only in a few of the cases does it reach the five per cent level of significance. The consistency of

this difference from year to year shows that structure of the sampling unit requires slight revision.

To see whether the positive correlation between the bunches in the same sample was mainly contributed by the adjacent pairs of bunches only or whether bunches in the same locality were also so correlated, the variances within samples for a few occasions were analysed into two parts, namely (1) the variance between pairs within the same sample and (2) the variance within pairs, i.e. between bunches in the same pair. In 1934 only the observations taken in the regularly sown crop were used for this analysis. Tables IX (A) and IX(B) give these variances. The differences in the 'between pair' variance and 'within pair' variance have been tested by the z-test and those differences which are significant are indicated in the table.

It will be found that in all the cases chosen for this analysis, the 'within samples' variance was significantly lower than the 'sampling variance', thereby showing the positive correlation between the bunches. Now it is found from Table IX(A) and IX(B) that only in some of the cases the 'within pair,' variance is lower than the 'between pair' variance. In other cases these two variances are equal. It appears therefore that the positive correlation within samples is not only contributed by the adjacent bunches in samples but between other bunches or pairs of bunches in the same locality.

The above results point to one conclusion, namely that the structure of the linear sampling unit requires a change if the sample is to be more representative of the crop. It may be mentioned here that for the wheat crop a sampling structure in which the units are taken on parallel rows has been found to be more efficient than a linear structure as in the present experiment [Kalamkar, 1932]. A similar structure, taking care to see that adjacent bunches are not taken in a sampling unit, may prove suitable for this crop also.

Efficiency of sampling. The sampling and experimental errors together with the 'non-sampling experimental error' (an estimate of what the experimental error would have been if the whole plot had been sampled) and the percentage information obtained by sampling as calculated from the formulae evolved by Yates and Zacopanay [1935] are shown in Tables X(A) and X (B). The percentage errors are given per plot (based on 32 bunches). The estimates of the experimental errors for the various observations are fairly within the usual limits, most of them lying within 6 per cent. As is to be expected the experimental errors are in general greater than the sampling errors. The percentage information obtained in the case of culms and heights varies from 70 to 90 per cent in most cases. It will be observed from the tables that both in the case of culms and height the percentage sampling errors in general decreased as the crop advanced in growth.

Comparison of the estimated and the actual yields. The yields of paddy and straw for the whole plot, as estimated from the sampling yields, are given in Table XI together with the corresponding actual yields obtained by entire harvest of the crop. Taking the total actual and estimated yields over all the plots in each year the differences have been expressed as a percentage of the actual yields below Table XI. Except in 1936, when there was an over estimation of $8 \cdot 82$ per cent the percentage differences are all small, showing that the sampling has been on the whole satisfactory. The plot errors as calculated from the actual and estimated yields are also found to agree fairly.

TABLE VIII(A)

'Sampling' and 'within samples' variances for each week's observations for number of culms, 1935—40

Week No.	1935		1936		1937		1938		1939		1940	
	Sampling variance	Within samples variance	Sampling variance	Within samples variance	Sampling variance	Within samples variance	Sampling variance	Within samples variance	Sampling variance	Within samples variance	Sampling variance	Within samples variance
1	1·7†	1·1	8·7‡	2·8	1·8	2·8	..	..	4·8	4·0	3·2	2·2
2	4·3‡	2·4	4·3†	2·8	1·8	2·1	..	..	..	..	5·7‡	2·9
3	5·8†	3·7	7·4	6·0	8·2	6·0	8·9	7·2	4·2	4·5	4·8	5·0
4	4·3	5·4	4·5	4·4	7·7	6·3	9·1	8·2	..	..	5·3	4·5
5	38·0‡	5·9	9·0†	6·0	9·8†	6·2	6·7	7·4	7·6	5·8	6·3	4·8
6	9·8‡	5·7	11·4‡	4·8	8·0	9·1	5·3	5·7	2·6	3·6	3·4	4·4
7	6·3	5·9	6·4†	4·3	6·4	7·2	7·5	5·2	4·1	2·9	6·0†	4·1
8	4·7	6·0	4·9	3·4	9·9	7·4	7·8	6·0	5·3‡	3·0	4·6	4·0
9	4·4	4·3	4·6	3·9	6·2	5·7	5·7	4·8	3·2	2·7	3·3	3·7
10	3·8	5·0	4·8	3·6	6·0	6·3	6·2	5·3	3·3	2·7	3·7	3·2
11	4·1	3·5	5·2	3·6	7·3	5·3	5·6	5·2	3·8	3·9	3·2	2·6
12	2·7	3·3	6·5‡	2·9	4·7	5·2	4·4	6·0	2·5	3·0	3·5	3·7
13	5·8‡	3·3	3·1	3·4	4·3	5·3	7·2	5·0	..	..	2·7	3·1
14	2·9	3·6	3·0	3·5	8·4†	5·2	5·6	5·7	..	..	..	..
15	..	..	2·9	3·5	6·0	5·3	..	..	..	..	..	..
16	..	..	..	..	..	..	..	..	..	..	4·0	3·1

† Significant at 5 per cent level

‡ Significant at 1 per cent level

TABLE VIII(B)

'Sampling' and 'within samples' variances for each week's observations for height in cm. and harvest characters, 1935—40

Week No.	1935		1936		1937		1938		1939		1940	
	Sampling variance	Within samples variance	Sampling variance	Within samples variance	Sampling variance	Within samples variance	Sampling variance	Within samples variance	Sampling variance	Within samples variance	Sampling variance	Within samples variance
1	4·0	3·8	6·7†	4·4	4·4‡	2·5	..	..	5·4‡	3·0	2·9	4·0
2	4·2	3·5	6·3‡	3·3	5·2‡	2·9	..	..	..	..	6·3‡	3·7
3	4·4†	3·0	3·4	3·2	5·6	4·0	5·3	4·4	5·0†	3·1	7·1	5·7
4	2·6	2·3	5·5	4·2	3·6	2·8	3·2	4·4	..	..	6·5†	3·9
5	11·5‡	4·8	8·9	7·3	3·2	4·2	7·2†	5·3	4·9	8·3	3·5	3·5
6	3·8	4·5	6·3	5·1	4·3	4·3	14·2‡	6·7	10·4	8·9	7·1	6·3
7	2·8	2·2	16·2	11·3	9·0	7·5	11·8	9·3	8·5	7·9	13·5†	8·4
8	15·3‡	8·9	12·0	12·1	23·6	25·1	23·0	17·0	17·6	21·1	7·2	7·2
9	17·5†	10·7	29·5‡	17·1	22·6	18·6	52·0†	33·0	68·3	50·8	36·6‡	21·4
10	31·6†	20·9	20·5	19·5	57·1	41·1	88·0	66·0	40·0	43·3	34·1	25·4
11	36·5	28·4	53·9	69·8	60·3†	40·2	44·0	63·0	47·0	42·0	45·4	43·3
12	45·5†	29·7	71·3‡	36·9	70·0†	43·8	33·0	32·0	39·9	38·7	38·9	38·5
13	41·9	44·2	54·4	58·2	79·7	55·7	53·0	36·0	..	..	30·4	38·1
14	48·5	52·9	83·1†	51·0	62·7†	42·0	41·0	31·0	..	..	..	..
15	..	..	78·7‡	41·4	93·6†	55·7	..	..	..	..	..	..
16	..	..	..	..	..	..	..	..	..	..	64·9	52·0
Panicle length in cm.	..	..	7·2	5·7	5·4	3·3	2·9	2·6	3·3	3·1	2·8	3·0
Straw yield in gm.	4·9	6·9	44·9	32·3	65·0†	13·4	40·7	29·8	16·1	16·8	30·8†	16·7
Paddy yield in gm.	13·3	21·1	33·0	23·0	47·2	40·8	45·0†	28·0	19·0	19·0	39·4†	26·5

† Significant at 5 per cent level ‡ Significant at 1 per cent level

TABLE IX(A)

Analysis of 'within sample' variance into the variance 'between pairs' of bunches and variance 'within pairs' of bunches for a few occasions, 1934

Due to	D. F.	Culms			Height		Paddy yield
		No. of week			No. of week		
		1	9	13	1	13	
Between pairs .	90	1·51	4·14	3·12	7·41	69·40‡	31·54†
Within pairs . .	120	2·00	4·25	3·04	5·61	36·52	20·73

TABLE IX(B)

Analysis of 'within sample' variance into variance 'between pairs' of bunches and variance 'within pairs' of bunches for a few occasions, 1937—40

Due to	D. F.	1937		1938 Paddy yield	1940	
		15th week			9th week	
		Height	Straw yield		Height	Straw yield
Between pairs . .	144	70·09‡	49·67†	31·30	25·93‡	16·89‡
Within pairs .	192	44·97	38·21	24·68	17·94	11·30

† Significant at 5 per cent level ‡ Significant at 1 per cent level

SUMMARY AND CONCLUSION

Growth observations on rice were made at the Karjat Rice Breeding Station, Karjat, for the years 1934—40. In 1934 the observations were made on two sets of plots, one of which was planted regularly and the other by the cultivator's method. Observations regarding the number of culms per bunch, height and number of leaves were recorded at intervals of a week for individual bunches, sampling units of eight bunches being chosen at random from the plots. At the time of harvest, the bunches chosen were separately cut and panicle length, straw yield and paddy yield were also recorded for each bunch.

For the regularly planted crop a linear sampling unit of eight bunches was adopted throughout while for the irregular crop in 1934, a square yard sampling structure was adopted where eight bunches along the frame of the square yard were observed.

The results of 1934 observations indicated that there was no material advantage in dividing the plots into sub-plots especially for the crop planted regularly. The regular and irregular crops exhibited significant differences in their features. The number of culms was higher for the irregular crop but the regular crop was the taller of the two during the later stages of growth.

Table X(A)

Culms

Sampling, experimental and non-sampling experimental errors and efficiency for all observations, 1934—40

Week No.	1934				1935				1936				1937				1938				1939				1940			
	Sampling	Experimental error	Non-Sampling experimental error	Efficiency	Sampling	Experimental error	Non-sampling experimental error	Efficiency	Sampling	Experimental error	Non-sampling experimental error	Efficiency	Sampling	Experimental error	Non-sampling experimental error	Efficiency	Sampling	Experimental error	Non-sampling experimental error	Efficiency	Sampling	Experimental error	Non-sampling experimental error	Efficiency	Sampling	Experimental error	Non-samplingexperimental error.	Efficiency
1	4·5	4·4	1·9	26	3·0	5·8	5·1	82	6·0	6·9	4·3	50	2·6	4·9	4·4	82	...	...	...	...	3·3	3·7	2·3	48	3·5	5·3	4·2	70
2	3·1	3·9	3·8	56	4·1	8·1	7·2	83	3·7	5·3	4·1	67	2·6	2·9	1·7	46	...	...	...	...	...	...	...	...	3·9	4·7	3·0	52
3	4·7	7·9	9·2	74	4·1	6·4	5·4	73	3·7	6·4	5·5	77	4·3	7·7	6·7	79	5·0	7·8	6·3	73	2·7	6·7	6·3	89	3·2	4·3	3·1	62
4	3·6	5·0	5·2	63	3·1	11·9	11·6	95	3·2	6·3	5·6	83	3·9	7·3	6·4	81	4·4	6·1	4·6	65	...	...	...	...	3·2	2·8	...	13
5	2·7	9·0	12·2	94	7·7	7·1	1·5	22	3·7	5·0	3·7	63	3·7	8·5	7·8	87	3·4	6·8	6·2	84	3·6	5·7	4·6	72	3·4	5·2	4·3	72
6	2·8	6·7	8·7	88	3·3	6·9	6·2	85	4·3	7·2	6·0	76	3·0	8·6	8·2	92	2·9	3·7	2·7	60	2·3	5·0	4·5	85	2·5	4·2	3·5	76
7	3·3	2·2	...	43	2·7	13·0	12·6	97	3·4	8·5	7·9	89	2·8	4·9	4·2	79	3·6	5·4	5·8	70	3·1	5·1	4·3	76	3·4	3·3	1·0	26
8	2·9	6·4	8·2	85	2·5	4·2	3·6	78	3·1	5·4	4·6	77	3·4	8·8	8·2	90	3·5	8·5	7·9	88	3·5	6·3	5·5	80	3·0	5·8	5·8	82
9	3·6	4·7	4·6	58	2·7	4·1	3·3	71	2·9	5·1	4·3	78	2·9	7·2	6·7	89	3·3	9·2	8·7	91	2·7	5·3	4·7	82	2·6	4·0	3·3	72
10	2·7	4·9	5·9	78	2·4	3·5	2·8	68	3·2	4·0	2·8	57	2·8	8·5	8·1	93	3·4	4·5	3·3	62	2·8	2·7	1·0	28	2·9	5·3	4·6	80
11	4·0	2·0	...	...	2·8	3·2	1·9	48	3·2	3·8	2·5	53	3·4	8·1	7·5	88	3·3	5·8	4·9	78	2·9	3·4	2·2	51	2·9	4·7	3·9	75
12	2·6	6·9	9·2	90	2·4	4·4	3·8	81	3·8	3·9	1·9	37	2·7	3·9	3·1	70	2·9	5·2	4·5	79	2·4	3·2	2·4	65	3·1	5·1	4·2	75
13	3·8	4·4	1·2	49	3·2	2·8	...	15	2·5	5·3	4·8	85	2·6	4·0	3·2	72	3·7	3·9	1·9	38	...	...	...	...	2·5	4·1	3·4	75
14	3·2	3·2	3·2	59	2·5	3·7	2·9	70	2·5	4·9	13·9	83	3·7	5·4	4·2	69	3·3	6·5	5·8	83	...	...	...	...	...	...	...	...
15	...	...	...	...	...	...	...	...	2·4	6·3	5·9	90	3·0	5·7	4·9	81	...	...	...	...	...	...	...	...	...	...	...	...
16	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·2	5·1	4·2	74

TABLE X(B)

Height and harvest characters

Sampling, experimental and non-sampling experimental errors and efficiency for all observations, 1934—40

Week No.	1934				1935				1936				1937				1938				1939				1940			
	Sampling	Experimental error	Non-sampling experimental error	Efficiency	Sampling	Experimental error	Non-sampling experimental error	Efficiency	Sampling	Experimental error	Non-sampling experimental error	Efficiency	Sampling	Experimental error	Non-sampling experimental error	Efficiency	Sampling	Experimental error	Non-sampling experimental error	Efficiency	Sampling	Experimental error	Non-sampling experimental error	Efficiency	Sampling	Experimental error	Non-sampling experimental error	Efficiency
1	4·6	4·5	2·0	26	3·5	4·6	3·3	61	3·3	5·5	4·6	75	3·9	4·8	3·3	57	...	...	...	...	2·9	7·5	7·0	90	2·7	6·3	5·8	88
2	2·3	1·7	...	...	3·0	7·7	7·2	90	2·9	11·3	11·0	96	3·5	5·5	4·5	74	...	...	...	...	...	...	...	...	3·3	4·6	3·5	65
3	3·1	3·9	3·7	56	2·4	5·2	4·7	86	2·0	4·3	3·9	85	3·1	4·8	3·9	72	2·9	5·0	4·2	77	2·2	4·7	4·2	85	2·9	7·4	6·9	89
4	2·0	4·9	6·4	88	1·7	2·6	2·1	70	2·3	9·6	9·4	96	2·0	3·2	2·6	75	1·9	3·4	3·0	81	...	...	...	...	2·4	2·0	...	4
5	1·7	5·9	8·1	100	3·3	3·7	2·2	47	2·7	4·8	4·1	79	1·8	2·7	2·2	71	2·4	6·0	5·6	89	1·8	2·9	2·4	75	1·6	2·0	1·3	55
6	2·7	2·1	...	...	1·7	7·4	7·2	97	2·1	7·3	7·1	95	1·8	4·6	4·3	89	3·1	5·0	4·7	79	2·0	3·3	2·7	74	2·2	2·5	1·5	49
7	2·3	4·9	6·1	84	1·4	3·1	2·8	86	3·1	2·9	0·8	25	2·1	4·0	3·5	81	2·3	4·0	3·5	79	1·7	3·0	2·5	77	2·6	6·5	6·1	89
8	2·6	3·8	4·3	71	2·4	5·1	4·6	86	2·2	5·8	5·4	91	3·5	4·6	3·4	61	2·7	4·3	4·1	79	1·8	4·1	3·8	88	1·7	4·4	4·1	90
9	2·4	6·2	8·2	89	2·1	4·1	3·6	83	2·9	3·0	1·5	39	2·4	3·5	2·3	67	2·9	3·2	1·8	45	2·5	4·5	3·9	79	3·3	8·0	7·4	89
10	2·9	3·8	3·9	59	2·2	4·5	4·1	85	1·9	4·7	4·3	89	2·6	5·2	4·6	83	2·6	6·3	5·8	87	1·5	4·0	3·8	91	2·1	5·2	4·9	89
11	2·3	3·7	4·3	72	1·1	5·1	4·9	93	2·1	9·6	9·5	97	1·7	3·1	2·7	80	1·4	2·3	1·9	75	1·5	2·5	2·1	77	1·6	8·2	8·1	97
12	1·5	2·5	2·9	73	1·3	2·7	2·4	83	1·6	2·1	1·5	59	1·5	2·5	2·1	77	1·1	1·6	1·3	68	1·3	2·7	2·4	84	1·1	5·2	5·1	97
13	1·8	3·8	4·9	84	1·2	2·3	2·1	82	1·3	1·9	1·4	66	1·5	1·8	1·1	51	1·4	2·3	1·9	75	...	...	...	...	1·0	5·0	4·9	97
14	1·2	3·0	3·9	89	1·3	3·1	2·8	88	1·7	1·7	0·9	39	1·3	2·7	2·4	84	1·2	2·1	1·7	77	...	...	...	...	...	...	...	...
15	...	...	...	...	...	...	...	...	1·6	2·3	1·8	67	1·7	2·1	1·4	56	...	...	...	...	...	...	...	...	...	...	...	...
16	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1·4	6·3	6·2	97
Planicle length	1·3	1·2	...	16	...	...	...	...	2·0	4·1	3·7	84	1·9	1·4	...	—16	1·3	1·7	1·1	57	1·5	2·5	2·1	75	1·3	2·5	2·2	82
Straw Yield	3·7	2·7	...	—68	1·0	1·7	1·4	75	3·8	6·4	5·3	76	4·3	6·3	4·9	69	4·0	5·6	4·2	65	2·8	6·8	6·3	89	3·8	7·6	6·7	83
paddy yield	4·7	8·3	10·6	79	2·7	4·0	3·2	70	3·8	3·6	1·0	25	3·9	4·9	3·5	59	4·4	7·7	6·6	78	3·1	7·6	7·1	89	5·2	6·7	5·4	65

TABLE XI

Estimated and actual yields of Paddy for various plots during 1934—40

Plot No.	1934		1935		1936		1937		1938		1939		1940	
	Actual lb.	Esti-mated lb.	Actual lb.	Esti-mated lb.	Actual lb.	Esti-mated lb.	Actual lb.	Esti-mated lb.	Actual lb.	Esti-mated lb.	Actual lb.	Esti-mated lb.	Actual lb.	Esti-mated lb.
1	18·68	17·87	..	..	8·99	9·51	11·90	12·37	9·55	9·44	10·44	10·43	9·65	8·84
2	16·97	17·56	..	..	8·99	9·86	12·81	12·84	10·01	10·16	10·44	10·55	9·01	8·78
3	16·30	16·47	..	..	8·98	10·04	12·83	12·62	10·67	11·05	10·14	9·98	8·91	8·95
4	15·27	15·09	..	..	9·12	9·89	12·68	11·92	10·78	11·86	10·47	9·67	9·43	9·66
5	14·71	14·72	..	..	8·92	10·10	12·46	12·29	10·73	11·15	9·77	9·76	8·65	8·51
6	..	..	..	..	9·07	10·00	12·32	12·37	9·50	8·96	9·48	9·37	8·84	8·68
7	..	..	Not available		9·43	10·46	11·83	11·39	9·62	9·85	9·36	9·31	9·14	9·12
8	..	..	..	..	9·13	10·08	12·71	11·91	10·35	10·12	8·90	8·86	8·69	8·77
9	..	..	..	..	9·22	10·07	12·60	12·07	10·22	10·02	9·17	9·11	9·19	9·07
10	..	..	..	..	8·94	9·59	12·55	13·22	10·29	10·43	9·15	9·35	8·75	9·06
11	..	..	..	..	9·44	10·03	12·59	11·38	10·13	10·93	8·97	8·98	8·42	8·64
12	..	..	..	..	8·87	9·09	10·95	11·32	9·67	10·31	8·08	7·91	7·49	7·16
Total	81·93	81·71	111·0	110·9	109·10	118·72	148·23	145·70	121·52	124·18	114·37	113·27	106·17	105·24
Plot error per cent	..	..	..	..	2·1	..	4·4	..	4·6	3·3	7·8	3·3	6·2	2·9

The panicle length at harvest of the irregular crop was shorter. There was no significant difference between the two crops in paddy yield; the irregular crop, however, gave a greater straw yield. Bunches within the same sample showed a positive correlation indicating the need for modifying the structure of the sampling unit.

The sampling was, however, found to be fairly efficient, as indicated by the percentage information obtained on each occasion. It is thus hoped that with a revised structure of the sampling unit, the same percentage for sampling may prove sufficient for sampling the crop.

Lastly, the actual yields of plots have been compared with yields as estimated by sampling and the two were found to agree within three per cent except for the year 1936.

As regards the modification in the linear sampling unit it is suggested that in future years the following structure may be tried.

First row . . $\circ\ \underbrace{\times\ \times\ \times}_{\text{Omit}}\ \circ\ \underbrace{\times\ \times\ \times}_{\text{Omit}}\ \circ\ \underbrace{\times\ \times}_{\text{Omit}}$

Second row . . $\underbrace{\times\ \times}_{\text{Omit}}\ \circ\ \underbrace{\times\ \times\ \times}_{\text{Omit}}\ \circ\ \underbrace{\times\ \times\ \times}_{\text{Omit}}\ \circ$

Each sample will consist of six bunches and four such sampling units may be taken from each plot to keep the percentage sampled the same as hitherto.

In concluding the authors desire to express their gratefulness to Dr L. A. Ramdas, Agricultural Meteorologist, for giving all the facilities required for such a cooperative effort of which the paper is the result. The keen interest which he showed at every stage of the investigation and analyses of the data afforded many opportunities to the authors to discuss the results with him and benefit by his suggestions and guidance. The authors also wish to record their thanks to the staff of the Rice Breeding Station at Karjat for recording the observations.

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A NEW IMPORTANT PEST OF WHEAT CROP IN INDIA

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(With one text-figure)

WHEAT crop in India has been rather free from any serious insect pest except sometime for the attack of termites in the seedling stage. The Pentatomid bug, *Eurygaster maura* Linn. (Fig. 1) and the allied species *E. integriceps* Put., *E. hottentota* F. and *E. austriaca* Schr. are known to be serious pests of wheat crop and other cereals in the Middle East—Syria, Iraq, Persia, Transcaspia, etc. and in central Europe and southern Russia [Sorauer, 1932]. The pest, however, is more widely distributed and is of some importance in almost whole of the European continent, North Africa, Caucasus, Siberia, Japan, China, East Indies, Canada, etc. [Oshanin, 1904]. During his recent visit to Tehran, the writer learnt from the Plant Protection Officer of Persia that *Eurygaster* was one of their most serious pests. It is probable that *Eurygaster* also occurs in Afghanistan.

FIG. 1. *Eurygaster maura* Linn. (×4½)

In India, the Imperial Pusa Collection contains specimens collected in 1919 and 1920. The first report of *E. maura* doing damage to wheat was, however, received in April 1926, when one Mr R. K. Nariman, M.I.C.E., F.R.G.S., Rasul P. O., Kulu, sent some specimens of this pest to the Imperial Entomologist for identification and advice. No further report of damage was received though the Imperial Pusa Collection contains some specimens collected from wheat ears at Fort Sandeman in June 1937, and at Kulu in June 1939. In June 1940, the Agricultural Officer, Baluchistan, sent for identification some specimens of *E. maura* to the Imperial Entomologist with the report that a large number of them had appeared in certain parts of the Zhob Valley and " were considered to have caused great damage to the irrigated wheat crop, causing the plants to dry up completely. " The pest was again in evidence in that area during May 1941 and at the same time in 1942,as is reported in the monthly diaries of the Director of Agriculture, Baluchistan. The Imperial Economic Botanist also sent some specimens to the Imperial Entomologist collected by his assistant from wheat and barley plants while on tour in Baluchistan in April 1941. Thus,

there is no doubt that the pest is fully established in Baluchistan though fortunately yet in a limited area, viz. Zhob district.

On account of the proximity of North-West Frontier Province to Zhob district and the fact that its climate is somewhat similar to that of Baluchistan and the Middle East countries, the writer seriously suspects that the pest also occurs in that Province.

Very little is yet known of the biology, life and seasonal history of the pest in India, but a great deal of information has been gathered in other countries which is summarized below.

This pest is known in the Palaearctic region since long time and has occurred in epidemic form in several countries during the last 20 years. Serious damage to wheat crop as a result of outbreak of this pest was reported from Hungary in 1931 [Manninger and Manninger Jr., 1934]; from the province of Verona in Italy [Malenotti, 1933]; and from northern Caucasus [Arkhangelskii, 1941]. The adult bugs are known to migrate from mountainous regions where they pass the late summer and winter to infest wheat fields in the plains in April when atmospheric temperature is 18°-24°C. This migration sometimes takes place in very large numbers, almost forming swarms. The bugs actively suck the juices of wheat plants throughout the day, passing the night under dry leaves or in other hiding places. As a result of their attack, the plants become stunted in growth and eventually wilt. Copulation takes place in 4-6 weeks after the appearance of the adults in the plains. The females lay their eggs generally on the lower part of the young wheat plants early in spring. A single female lays up to 180 eggs in batches of about a dozen each. The eggs are at first green in colour, but later on turn black. The incubation period of the egg is 10-14 days. The newly hatched nymphs suck in the beginning on the upper part of the young shoots, later on the infestation from thence spreads to the ears when the grains are in 'milky' stage, causing them to turn white. The infestation spreads from one field to another, and continues up to harvest time, by which time the bugs are also fully grown. It is stated that as a result of feeding by the bugs, apart from the effect of desapping, the affected shoots and the young ears are killed owing to the introduction of a proteolytic enzyme into the tissues resulting in the arrestation of the formation of seed [Manninger and Manninger Jr., 1933]. Thus, the quality of gluten in the affected wheat grain is very much depreciated and the flour obtained from it becomes unsuitable for baking purposes [Manninger and Manninger Jr., 1933; Schulze, 1936; and Arkhangelskii, 1941]. This happens even if about 5 per cent of the grains are punctured. After the wheat crop is harvested, the adults go back to their winter-quarters in the hills where they hibernate under fallen leaves in forests, dense growth of vegetation, protective strips of trees, or under lumps of soil up to a depth of 50 cm. With the rise of temperature in spring, the bugs once again become active and fly about in swarms towards the plains to infest the wheat crop as described above. Besides wheat, the hosts of the pest are a variety of other cereals, e.g., oats, maize, barley, several grasses (Gramineae), weeds of the families Cyperaceae, Umbelliferae, Compositae, etc. [Schulze, 1936], and sunn-hemp (*Crotalaria juncea*) in Mesopotamia [Silvestri, 1934].

Important natural enemies of this bug include Scelionid egg-parasites of the genus *Telenomus* which are considered to be very efficient in as much

as they can parasitize up to 96 per cent of the host-eggs, two genera of Tachinids, viz. *Phasia* and *Clytiomyia* and an Asilid [Dobrovolski, 1913 ; Malenotti, 1933 ; Tischler, 1938]. It is also interesting to note that Chappellier [1923] found a large number of nymphs of this bug in the body of the nestlings of the common rook.

The control of this pest on a field scale has been attempted in several countries. In most cases effort is made to kill the pest by strong sprays or actually burning the rubbish in the hills harbouring the pest during winter. The places where the pest hibernates or aestivates are sought with a view to effectively killing it. In the plains, the compulsory collection (by law) of these bugs in receptacles containing a contact poison has been reported to be useful. The other methods of control [Arkhangelskii, 1941] recommended are (*i*) ploughing the stubbles in harvested fields up to a depth of 8 in., followed by harrowing ; (*ii*) spraying the affected plants with 5 per cent solution of barium chloride ; (*iii*) growing grasses as trap-crops and spraying them with pyrethrum ; and (*iv*) artificial breeding and liberation of the egg-parasites, *Telenomus* spp.

It need hardly be emphasized that it is very essential that the pest should be carefully studied in Baluchistan throughout the year to determine its seasonal-history and alternate food-plants. Then it would be possible to devise suitable measures for its control as well as against its spread to other areas. The pest should also be looked for in the North-West Frontier Province, and the Punjab (Kulu and other hilly and sub-mountainous areas) ; and careful vigilance should be exercised over its increase in numbers. In view of its seasonal and life-history in other countries, its migratory habits and the variety of its alternate food-plants, the writer fears that it will be very difficult to control the pest if it once gets established in India.

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